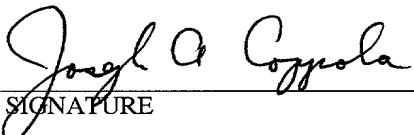


FORM PTO-1390 (REV. 11-98)		U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE		ATTORNEY'S DOCKET NUMBER 20052YP
<b>TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371</b>				U.S. APPLICATION NO. (If known, see 37 CFR 1.5) <b>09/601582</b>
INTERNATIONAL APPLICATION NO. PCT/US99/02361	INTERNATIONAL FILING DATE 03 February 1999	PRIORITY DATE CLAIMED 05 February 1998		
TITLE OF INVENTION <b>NOVEL GABAB RECEPTOR DNA SEQUENCES</b>				
APPLICANT(S) FOR DO/EO/US Qingyun Liu, Terrence McDonald, Timothy P. Bonnert, Gordon Ng, Lee F. Kolakowski, Jr., Janet Clark, Tom I. Bonner				
<p><b>Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:</b></p> <p>1. <input checked="" type="checkbox"/> This is a <b>FIRST</b> submission of items concerning a filing under 35 U.S.C. 371.</p> <p>2. <input type="checkbox"/> This is a <b>SECOND</b> or <b>SUBSEQUENT</b> submission of items concerning a filing under 35 U.S.C. 371.</p> <p>3. <input type="checkbox"/> This is an express request to begin national examination procedures [35 U.S.C. 371(f)] at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(l).</p> <p>4. <input checked="" type="checkbox"/> A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.</p> <p>5. <input checked="" type="checkbox"/> A copy of the International Application as filed [35 U.S.C. 371(c)(2)].</p> <p>a. <input checked="" type="checkbox"/> is transmitted herewith (required only if not transmitted by the International Bureau).</p> <p>b. <input type="checkbox"/> has been transmitted by the International Bureau.</p> <p>c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US).</p> <p>6. <input type="checkbox"/> A translation of the International Application into English [35 U.S.C. 371(c)(2)].</p> <p>7. <input type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 [35 U.S.C. 371(c)(3)].</p> <p>a. <input type="checkbox"/> are transmitted herewith (required only if not transmitted by the International Bureau).</p> <p>b. <input type="checkbox"/> have been transmitted by the International Bureau.</p> <p>c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.</p> <p>d. <input type="checkbox"/> have not been made and will not be made.</p> <p>8. <input type="checkbox"/> A translation of the amendments to the claims under PCT Article 19 [35 U.S.C. 371(c)(3)].</p> <p>9. <input checked="" type="checkbox"/> An oath or declaration of the inventor(s) [35 U.S.C. 371(c)(4)].</p> <p>10. <input type="checkbox"/> A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 [35 U.S.C. 371(c)(5)].</p>				
<p><b>Items 11 to 16 below concern other document(s) or information included:</b></p> <p>11. <input type="checkbox"/> An Information Disclosure Statement under 37 CFR 1.97 and 1.98.</p> <p>12. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.</p> <p>13. <input type="checkbox"/> A <b>FIRST</b> preliminary amendment.</p> <p><input type="checkbox"/> A <b>SECOND</b> or <b>SUBSEQUENT</b> preliminary amendment.</p> <p>14. <input type="checkbox"/> A substitute specification.</p> <p>15. <input type="checkbox"/> A change of power of attorney and/or address letter.</p> <p>16. <input type="checkbox"/> Other items or information:</p>				
<p><b>EXPRESS MAIL CERTIFICATE</b></p> <p>DATE OF DEPOSIT <u>August 2, 2000</u></p> <p>EXPRESS MAIL NO. <u>EK091635800US</u></p> <p>I HEREBY CERTIFY THAT THIS CORRESPONDENCE IS BEING DEPOSITED WITH THE UNITED STATES POSTAL SERVICE AS EXPRESS MAIL "POST OFFICE TO ADDRESSEE" BEFORE 5 P.M. ON THE ABOVE DATE IN AN ENVELOPE ADDRESSED TO ASSISTANT COMMISSIONER FOR PATENTS, WASHINGTON, D.C. 20234.</p> <p>MAILED BY <u>Linda Scher</u></p> <p>DATE <u>August 2, 2000</u></p>				

U.S. APPLICATION NO. (If known, see 37 CFR 1.5) <b>09/601582</b>	INTERNATIONAL APPLICATION NO. PCT/US99/02361	ATTORNEY'S DOCKET NUMBER 20052YP		
17. <input checked="" type="checkbox"/> The following fees are submitted:		CALCULATIONS		
<b>BASIC NATIONAL FEE [37 CFR 1.492(a)(1)-(5)]:</b>		PTO USE ONLY		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee [37 CFR 1.445(a)(2)] paid to USPTO and International Search Report not prepared by the EPO or JPO..... <b>\$970.00</b>				
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO..... <b>\$840.00</b>				
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee [37 CFR 1.445(a)(2)] paid to USPTO..... <b>\$690.00</b>				
International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4)..... <b>\$670.00</b>				
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4)..... <b>\$96.00</b>				
<b>ENTER APPROPRIATE BASIC FEE AMOUNT</b> =		\$96.00		
Surcharge of <b>\$130.00</b> for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date [37 CFR 1.492(e)].		\$0.00		
Claims	Number Filed	Number Extra	Rate	
Total Claims	19 - 20 =	0	X <b>\$18.00</b>	\$0.00
Independent Claims	11 - 3 =	8	X <b>\$78.00</b>	\$624.00
Multiple dependent claim(s) (if applicable)		0	+ <b>\$260.00</b>	\$0.00
<b>TOTAL OF ABOVE CALCULATIONS</b> =		\$720.00		
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).				
<b>SUBTOTAL</b> =		\$720.00		
Processing fee of <b>\$130.00</b> for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date [37 CFR 1.492(f)].		+ \$0.00		
<b>TOTAL NATIONAL FEE</b> =		\$720.00		
Fee for recording the enclosed assignment [37 CFR 1.21(h)]. The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). <b>\$40.00</b> per property.		+ \$0.00		
<b>TOTAL FEES ENCLOSED</b> =		\$720.00		
		Amount to be refunded		
		charged		
<p>a. <input type="checkbox"/> A check in the amount of \$ _____ to cover the above fees is enclosed.</p> <p>b. <input checked="" type="checkbox"/> Please charge my Deposit Account No. <u>13-2755</u> in the amount of <u>\$720.00</u> to cover the above fees. A duplicate copy of this sheet is enclosed.</p> <p>c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to the Deposit Account No. <u>13-2755</u>. A duplicate copy of this sheet is enclosed.</p>				
<p><b>NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive [37 CFR 1.137(a) or (b)] must be filed and granted to restore the application to pending status.</b></p>				
SEND ALL CORRESPONDENCE TO:				
<p>MERCK &amp; CO., INC. Patent Department, RY60-30 P.O. Box 2000 126 East Lincoln Avenue Rahway, New Jersey 07065-0970</p>				
<p>DATE: <u>2 AUGUST 2000</u></p>				
<p>PHONE #: <u>(732) 594-6734</u></p>				
<p> SIGNATURE Joseph A. Coppola NAME 38,413 REGISTRATION NUMBER</p>				

TITLE OF THE INVENTION  
NOVEL GABAB RECEPTOR DNA SEQUENCES

## CROSS-REFERENCE TO RELATED APPLICATIONS

5 This application claims the benefit of U.S. Provisional Application No. 60073,767, filed February 5, 1998, the contents of which are incorporated herein by reference in their entirety.

## STATEMENT REGARDING FEDERALLY-SPONSORED R&amp;D

10 Not applicable.

## REFERENCE TO MICROFICHE APPENDIX

Not applicable.

## 15 FIELD OF THE INVENTION

The present invention is directed to a novel human DNA sequence encoding HG20, a subunit of the GABA<sub>B</sub> receptor, the protein encoded by the DNA, and uses thereof. The present invention also is directed to the murine GABA<sub>B1a</sub> subunit of the GABA<sub>B</sub> receptor as well as to methods of combining an HG20 subunit 20 with a GABA<sub>B1a</sub> subunit to form a GABA<sub>B</sub> receptor having functional activity.

## BACKGROUND OF THE INVENTION

Amino acids such as glutamic acid,  $\gamma$ -amino-butyric acid (GABA), and glycine are neurotransmitters that bind to specific receptors in the vertebrate nervous 25 system and mediate synaptic transmission. Of these amino acids, GABA is the most widely distributed amino acid inhibitory neurotransmitter in the vertebrate central nervous system. The biological activities of GABA are mediated by three types of GABA receptors: ionotropic GABA<sub>A</sub> receptors, metabotropic GABA<sub>B</sub> receptors, and ionotropic GABA<sub>C</sub> receptors. Each type of receptor has its own characteristic 30 molecular structure, pattern of gene expression, agonist and antagonist mediated pharmacological effects, and spectrum of physiological activities.

GABA<sub>A</sub> receptors mediate fast synaptic inhibition. They are heterooligomeric proteins (most likely pentamers) containing  $\alpha$ ,  $\beta$ ,  $\gamma$ , and perhaps  $\delta$ , subunits that function as ligand-gated Cl<sup>-</sup> channels and have binding sites for

benzodiazepines, barbiturates, and neuroactive steroids. Bicuculline is a widely used antagonist of GABA<sub>A</sub> receptors. Bicuculline is selective for GABA<sub>A</sub> receptors in that it has no effect on GABA<sub>B</sub> or GABA<sub>C</sub> receptors. The expression of GABA<sub>A</sub> receptors has been observed in a variety of brain structures (see, e.g., McKernan & 5 Whiting, 1996, Trends Neurosci. 16:139-143; Sequier et al., 1988, Proc. Natl. Acad. Sci. USA 85:7815-7819).

GABA<sub>C</sub> receptors are ligand-gated Cl<sup>-</sup> channels found in the vertebrate retina. They can be distinguished from GABA<sub>A</sub> and GABA<sub>B</sub> receptors in that they are insensitive to the GABA<sub>A</sub> receptor antagonist bicuculline and the 10 GABA<sub>B</sub> receptor agonist (-)baclofen but are selectively activated by *cis*-4-aminocrotonic acid. GABA<sub>C</sub> receptors are composed of homooligomers of a category of GABA receptor subunits known as “ $\rho$ ” subunits, the best-studied of which are  $\rho 1$  and  $\rho 2$ .  $\rho 1$  and  $\rho 2$  share 74% amino acid sequence identity but are only about 30-38% identical in amino acid sequence when compared to GABA<sub>A</sub> receptor 15 subunits. For a review of GABA<sub>C</sub> receptors, see Bormann & Feigenspan, 1995, Trends Neurosci. 18:515-518.

GABA<sub>B</sub> receptors play a role in the mediation of late inhibitory postsynaptic potentials (IPSPs). GABA<sub>B</sub> receptors belong to the superfamily of seven transmembrane-spanning G-protein coupled receptors that are coupled through 20 G-proteins to neuronal K<sup>+</sup> or Ca<sup>++</sup> channels. GABA<sub>B</sub> receptors are coupled through G-proteins to neuronal K<sup>+</sup> or Ca<sup>++</sup> channels, and receptor activation increases K<sup>+</sup> or decreases Ca<sup>++</sup> conductance and also inhibits or potentiates stimulated adenylyl cyclase activity. The expression of GABA<sub>B</sub> receptors is widely distributed in the mammalian brain (e.g., frontal cortex, cerebellar molecular layer, interpeduncular 25 nucleus) and has been observed in many peripheral organs as well.

A large number of pharmacological activities have been attributed to GABA<sub>B</sub> receptor activation, e.g., analgesia; hypothermia; catatonia; hypotension; reduction of memory consolidation and retention; and stimulation of insulin, growth hormone, and glucagon release (see Bowery, 1989, Trends Pharmacol. Sci. 10:401- 30 407, for a review.) It is well accepted that GABA<sub>B</sub> receptor agonists and antagonists are pharmacologically useful. For example, the GABA<sub>B</sub> receptor agonist (-)baclofen, a structural analog of GABA, is a clinically effective muscle relaxant (Bowery & Pratt, 1992, Arzneim.-Forsch./Drug Res. 42:215-223). (-)baclofen, as part of a

racemic mixture with (+)baclofen, has been sold in the United States as a muscle relaxant under the name LIORESAL® since 1972.

GABA<sub>B</sub> receptors represent a large family of related proteins, new family members of which are still being discovered. For example, Kaupmann et al., 5 1997, *Nature* 386:239-246 (Kaupmann) reported the cloning and expression of two members of the rat GABA<sub>B</sub> receptor family, GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b. A variety of experiments using known agonists and antagonists of GABA<sub>B</sub> receptors seemed to indicate that GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b represented rat GABA<sub>B</sub> receptors. This conclusion was based primarily on the ability of GABA<sub>B</sub>R1a and 10 GABA<sub>B</sub>R1b to bind agonists and antagonist of GABA<sub>B</sub> receptors with the expected rank order, based upon studies of rat cerebral cortex GABA<sub>B</sub> receptors. However, there were data that did not fit the theory that Kaupmann had cloned the pharmacologically and functionally active GABA<sub>B</sub> receptor. For example, 15 Kaupmann noted that agonists had significantly lower binding affinity to recombinant GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b as opposed to native GABA<sub>B</sub> receptors. Also, Couve et al., 1998, *J. Biol. Chem.* 273:26361-26367 showed that recombinantly expressed GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b failed to target correctly to the plasma membrane and failed to give rise to functional GABA<sub>B</sub> receptors when expressed in a variety of cell types.

20 Examination of the amino acid and gene sequence of GABA<sub>B</sub>R1a led Kaupmann to propose a structure for GABA<sub>B</sub>R1a similar to that of the metabotropic glutamate receptor gene family. The metabotropic glutamate receptor family comprises eight glutamate binding receptors and five calcium sensing receptors which exhibit a signal peptide sequence followed by a large N-terminal domain believed to 25 represent the ligand binding pocket that precedes seven transmembrane spanning domains. The hallmark seven transmembrane spanning domains are typical of G-protein coupled receptors (GPCRs), although metabotropic glutamate receptors and GABA<sub>B</sub>R1a are considerably larger than most GPCRs and contain a signal peptide sequence. No significant amino acid sequence similarities were found between 30 GABA<sub>B</sub>R1a and GABA<sub>A</sub> receptors, GABA<sub>C</sub> receptors, or other typical GPCRs.

Despite work such as that of Kaupmann, pharmacological and physiological evidence indicates that a large number of amino acid binding GABA<sub>B</sub> receptors remain to be cloned and expressed in recombinant systems where agonists and antagonists can be efficiently identified. In particular, it would be extremely

valuable to be able to recombinantly express GABA<sub>B</sub> receptors in such a manner that not only pharmacologically relevant ligand binding properties would be exhibited by the recombinant receptors, but also such that the recombinant receptors would show proper functional activity.

5

## SUMMARY OF THE INVENTION

The present invention is directed to a novel human DNA that encodes a GABA<sub>B</sub> receptor subunit, HG20. The DNA encoding HG20 is substantially free from other nucleic acids and has the nucleotide sequence shown in SEQ.ID.NO.:1. 10 Also provided is an HG20 protein encoded by the novel DNA sequence. The HG20 protein is substantially free from other proteins and has the amino acid sequence shown in SEQ.ID.NO.:2. Methods of expressing HG20 in recombinant systems and of identifying agonists and antagonists of HG20 are provided.

The present invention is also directed to a novel murine DNA that encodes a GABA<sub>B</sub> receptor subunit, GABA<sub>B</sub>R1a. The DNA encoding GABA<sub>B</sub>R1a is substantially free from other nucleic acids and has the nucleotide sequence shown in SEQ.ID.NO.:19. Also provided is a GABA<sub>B</sub>R1a protein encoded by the novel DNA sequence. The GABA<sub>B</sub>R1a protein is substantially free from other proteins and has the amino acid sequence shown in SEQ.ID.NO.:20. Methods of expressing GABA<sub>B</sub>R1a in recombinant systems and of identifying agonists and antagonists of HG20 are provided. 20

Also provided by the present invention are methods of co-expressing HG20 and GABA<sub>B</sub>R1a in the same cells. Such co-expression results in the production of a GABA<sub>B</sub> receptor that exhibits expected functional properties of 25 GABA<sub>B</sub> receptors as well as expected ligand binding properties. Recombinant cells co-expressing HG20 and GABA<sub>B</sub>R1a are provided as well as methods of utilizing such recombinant cells to identify agonists and antagonists of GABA<sub>B</sub> receptors.

## BRIEF DESCRIPTION OF THE DRAWINGS

30 Figure 1A-B shows the complete cDNA sequence of HG20 (SEQ.ID.NO.:1).

Figure 2 shows the complete amino acid sequence of HG20 (SEQ.ID.NO.:2).

Figure 3A-B shows predicted signal peptide cleavage sites of HG20. All sequences shown are portions of SEQ.ID.NO.:2.

Figure 4 shows *in situ* analysis of the expression of HG20 RNA in squirrel monkey brain.

5 Figure 5A shows *in vitro* coupled transcription/translation of a chimeric FLAG epitope-HG20 (amino acids 52-941) protein.

Figure 5B shows the expression in COS-7 cells and melanophores of a chimeric FLAG epitope-HG20 (amino acids 52-941) protein.

10 Figure 6 shows a comparison of the amino acid sequences of a portion of the N-terminus of HG20 protein and the ligand binding domain of the *Pseudomonas aeruginosa* amino acid binding protein LIVAT-BP (Swiss Protein database accession number P21175). The upper sequence shown is from HG20 and corresponds to amino acids 63-259 of SEQ.ID.NO.:2. The lower sequence shown is from *Pseudomonas aeruginosa* LIVAT-BP and is SEQ.ID.NO.:16.

15 Figure 7 shows expression in mammalian cells of a chimeric HG20 protein.

Figure 8 shows a comparison of the amino acid sequences of HG20 and GABA<sub>B</sub>R1b. The HG20 sequence is SEQ.ID.NO.:2. The GABA<sub>B</sub>R1b sequence is SEQ.ID.NO.:17.

20 Figure 9 shows the expression of recombinant GABA<sub>B</sub>R1a and HG20 in COS-7 cells. Lanes 1 and 2 show [<sup>125</sup>I]CGP71872 photolabeling of recombinant murine GABA<sub>B</sub>R1a monomer and dimer in the presence (+) and absence (-) of 1 μM unlabeled CGP71872. Lanes 3 and 4 show that GABA<sub>B</sub>R1a antibodies 1713.1-1713.2 confirmed (+) expression of recombinantly expressed murine GABA<sub>B</sub>R1a (referred to as mgb1a here) and absence (-) in pcDNA3.1 mock transfected cells. Lanes 5 and 6 show [<sup>125</sup>I]CGP71872 photolabeling of human FLAG-HG20 in the presence (+) and absence (-) of 1 μM unlabeled CGP71872. Lanes 7 and 8 show that an anti-FLAG antibody confirmed (+) the expression of FLAG-HG20 (referred to as FLAG-gb2 here) and its absence (-) in pcDNA3.1 mock transfected cells.

25 30 Experimental details were as in Examples 7-9 and 20 except that COS-7 rather than COS-1 cells were used.

Figure 10 shows co-localization of mRNA for HG20 and GABA<sub>B</sub>R1a by *in situ* hybridization histochemistry in rat parietal cortex. Adjacent coronal sections of rat brain showing parietal cortex hybridized with radiolabelled

GABA<sub>B</sub>R1a (A) and HG20 (B) probes. Rat GABA<sub>B</sub>R1a and HG20 probes were labelled using <sup>35</sup>S-UTP (A, B, and D), and autoradiograms were developed after 4 weeks. For co-localization studies, the rat GABA<sub>B</sub>R1a probe was digoxigenin labelled and developed using anti-digoxigenin HRP, the TSA amplification method 5 and biotinyl tyramide followed by streptavidin-conjugated CY3 (C). (D) shows autoradiography of the same field as in (C), denoting hybridization to HG20 mRNA. (E) is an overlay of images (C) and (D). Arrows denote some of the double-labelled cells. Scale bar = 0.5 mm in (A) and (B); scale bar = 50  $\mu$ m in (C-E).

Figure 11 shows functional complementation following co-expression 10 of GABA<sub>B</sub>R1a and HG20 in *Xenopus* melanophores. GABA mediated a dose-dependent aggregation response in melanophores co-expressing murine GABA<sub>B</sub>R1a and FLAG-HG20 (■) that could be blocked with 100 nM (▼) and 1  $\mu$ M CGP71872 (▲). The response of GABA on mock-transfected cells is shown (●) as well as a control cannabinoid receptor subtype 2 response to HU210 ligand (inset). This 15 experiment is representative of n=4.

Figure 12 shows GABA<sub>B</sub> receptor modulation of forskolin-stimulated 20 cAMP synthesis in HEK293 cells. HEK293 cells stably expressing HG20 (hgb2-42) or GABA<sub>B</sub>R1a (rgb1a-50) were transiently transfected with GABA<sub>B</sub>R1a and HG20 expression plasmids to examine the effect of receptor co-expression on modulation of cAMP synthesis. All transfected cells were tested with 300  $\mu$ M baclofen or GABA (with 100  $\mu$ M AOAA and 100  $\mu$ M nipecotic acid) in the absence of forskolin and 30  $\mu$ M baclofen or GABA in the presence of 10  $\mu$ M forskolin. Wild-type HEK293 cells were tested with 250  $\mu$ M baclofen or 250  $\mu$ M GABA in the presence of 10  $\mu$ M 25 forskolin. Data are presented as the percent of total cAMP synthesized in the presence of forskolin only. The data presented are from single representative experiments that have been replicated twice. Fsk, forskolin; B, baclofen; G, GABA with AOAA and nipecotic acid. The two right-most set of bar graphs (labeled "B + Fsk" and "G + Fsk") show that in cells expressing both GABA<sub>B</sub>R1a and HG20 (rgb1a-50/hgb2 cells (□) and hgb2-42/rgb1a cells (■)), baclofen and GABA were 30 able to mediate significant reductions in cAMP levels.

Figure 13 shows that co-expression of GABA<sub>B</sub>R1a and HG20 permits inwardly rectifying potassium channel (GIRK or Kir) activation in *Xenopus* oocytes. (A) Representative current families of Kir 3.1/3.2. Currents were evoked by 500 msec voltage commands from a holding potential of -10 mV, delivered in 20 mV

increments from -140 to 60 mV. (B) In a protocol designed to measure the effects of various receptors on Kir currents, oocytes were held at -80 mV (a potential where significant inward current is measured). Expression of GABA<sub>B</sub>R1a or HG20 alone (with or without Gα1) resulted in no modulation of current after GABA treatment.

5 Co-expression of GABA<sub>B</sub>R1a and FLAG-HG20 receptors followed by treatment with 100 μM GABA resulted in stimulation of Kir 3.1/3.2. Shown are representative traces from at least three independent experiments under each condition.

Figure 14 shows immunoblotting of murine GABA<sub>B</sub>R1a and FLAG-HG20 transiently expressed in COS-7 cells. Digitonin-solubilized and anti-FLAG antibody immunoprecipitated membrane proteins were immunoblotted following SDS-PAGE with GABA<sub>B</sub>R1a antibodies 1713.1-1713.2. The conditions are as follows: mock pcDNA3.1 vector transfected cells (lane 1), FLAG-HG20 expressing cells (lane 2), murine GABA<sub>B</sub>R1a expressing cells (lane 3), and cells coexpressing murine GABA<sub>B</sub>R1a and FLAG-HG20 (lane 4). The immunoreactive band corresponding to the GABA<sub>B</sub>R1a /HG20 heterodimer as well as a band corresponding to the predicted GABA<sub>B</sub>R1a monomer are denoted by arrows.

10 Figure 15 shows the complete cDNA sequence of murine GABA<sub>B</sub>R1a (SEQ.ID.NO.:19). The sequence shown has been deposited in GenBank (accession number AF114168).

15 Figure 16 shows the complete amino acid sequence of murine GABA<sub>B</sub>R1a (SEQ.ID.NO.:20). The sequence shown has been deposited in GenBank (accession number AF114168).

20 Figure 17A-B shows the results of experiments with N- and C-terminal fragments of murine GABA<sub>B</sub>R1a. Figure 17A shows the results of coupled *in vitro* transcription/translation reactions; lane 1 = blank; lane 2 = full-length GABA<sub>B</sub>R1a; lane 3 = N-terminal fragment of GABA<sub>B</sub>R1a; lane 4 = C-terminal fragment of GABA<sub>B</sub>R1a. Figure 17B shows the results of [<sup>125</sup>I]CGP71872 photoaffinity labeling; lane 1 = N-terminal fragment of GABA<sub>B</sub>R1a; lane 2 = N-terminal fragment of GABA<sub>B</sub>R1a in the presence of GABA; lane 3 = C-terminal fragment of GABA<sub>B</sub>R1a; lane 4 = C-terminal fragment of GABA<sub>B</sub>R1a in the presence of GABA.

25 Figure 18A-B shows the amino acid sequence (Figure 18A) (SEQ.ID.NO.:21) and nucleotide sequence (Figure 18B) (SEQ.ID.NO.:22) (GenBank accession number AJ012185) of a human GABA<sub>B</sub>R1a.

Figure 19A-B shows the nucleotide sequence (SEQ.ID.NO.:23) (GenBank accession number Y11044) of a human GABA<sub>B</sub>R1a.

Figure 20 shows a framework map of chromosome 9. The locations of the HG20 gene (referred to as “GPR 51”), markers, and the HSN-1 locus are 5 indicated.

Figure 21 shows a hydropathy plot for murine GABA<sub>B</sub>R1a.

Figure 22 shows a family tree of genes related to HG20. Abbreviations are as follows: hGB1a = human GABA<sub>B</sub>R1a; mGB1a = mouse GABA<sub>B</sub>R1a; rGB1a = rat GABA<sub>B</sub>R1a; hGB1b = human GABA<sub>B</sub>R1b; rGB1b = rat GABA<sub>B</sub>R1b; ceGB1b 10 = a *C. elegans* gene related to mammalian GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b; hGB2 = human HG20; ceGB2 = a *C. elegans* gene related to human HG20; MGRDROME = a metabotropic glutamate receptor from *Drosophila melanogaster*; MGR2 HUMAN = human metabotropic glutamate receptor 2; MGR3 HUMAN = human metabotropic glutamate receptor 3; MGR6 HUMAN = human metabotropic glutamate receptor 6; 15 MGR4 HUMAN = human metabotropic glutamate receptor 4; MGR7 HUMAN = human metabotropic glutamate receptor 7; MGR8 HUMAN = human metabotropic glutamate receptor 8; MGR1 HUMAN = human metabotropic glutamate receptor 1; MGR5 HUMAN = human metabotropic glutamate receptor 5.

Figure 23 shows the coiled-coil domains in the C-termini of human 20 GABA<sub>B</sub>R1a and HG20. The upper sequence is from human GABA<sub>B</sub>R1a and is positions 886-949 of SEQ.ID.NO.:21. The lower sequence is from HG20 and is positions 756-829 of SEQ.ID.NO.:2.

Figure 24 shows a comparison of the amino acid sequences of human 25 GABA<sub>B</sub>R1a (referred to as “Human GABA-B1aR,” SEQ.ID.NO.:21); the proteins encoded by two genes from *C. elegans* (*C. elegans* GABA-B1 = SEQ.ID.NO.:42 and *C. elegans* GABA-B2 = SEQ.ID.NO.:43); and HG20) (referred to as “Human GABA-B2,” (SEQ.ID.NO.:2). The *C. elegans* genes have been predicted from *C. elegans* DNA sequence alone. ZK180 accession number: U58748 is predicted to be GABA-B2 and Y41G9. Contig99 and Y76F7.Contig73 were obtained from the Sanger *C. elegans* genomic sequence database and are predicted to be GABA-B1. 30

Figure 25A-D shows co-immunoprecipitation of the murine GABA<sub>B</sub>R1a and FLAG-HG20 receptor subunits and immunoblotting using reciprocal receptor subunit antibodies. Murine GABA<sub>B</sub>R1a and FLAG-HG20 receptors were expressed individually or co-expressed in COS-7 cells. Figure 25A

shows the results of immunoblotting using an anti-murine GABA<sub>B</sub>R1a antibody. Immunoblot of the solubilized membranes using murine GABA<sub>B</sub>R1a antibodies 1713.1-1713.2 shows selective expression of murine GABA<sub>B</sub>R1a in murine GABA<sub>B</sub>R1a alone expressing cells (lane 3) and murine GABA<sub>B</sub>R1a /FLAG-HG20 5 co-expressing cells (lane 4), but not in mock transfected and FLAG-HG20 alone expressing cells (lanes 1 and 2). Staining of GABA<sub>B</sub>R1a subunits in co-expressing cells is more intense compared to cells expressing the GABA<sub>B</sub>R1a subunit alone, suggesting that HG20 subunits facilitate GABA<sub>B</sub>R1a expression. Figure 25B shows the results of immunoblotting using an anti-FLAG-HG20 antibody. Immunoblotting 10 of the solubilized membranes using the anti-FLAG-HG20 antibody shows selective expression of FLAG-HG20 subunits in FLAG-HG20 alone expressing cells (lane 6) and murine GABA<sub>B</sub>R1a /FLAG-HG20 co-expressing cells (lane 8), but not in mock transfected and murine GABA<sub>B</sub>R1a alone expressing cells (lanes 5 and 7). Staining of HG20 subunits in co-expressing cells is more intense compared to cells expressing 15 the HG20 subunit alone, suggesting that GABA<sub>B</sub>R1a subunits facilitate HG20 expression. Figure 25C shows the results of immunoprecipitation with an anti-FLAG-HG20 antibody followed by immunoblotting with an anti-murine GABA<sub>B</sub>R1a antibody. GABA<sub>B</sub>R1a /HG20 heterodimers are observed only in murine GABA<sub>B</sub>R1a /FLAG-HG20 co-expressing cells due to the fact that the GABA<sub>B</sub>R1a subunit was 20 co-immunoprecipitated with the FLAG-HG20 subunit using the FLAG antibody and detected with GABA<sub>B</sub>R1a antibodies (lane 12). GABA<sub>B</sub>R1a subunits are not detected in mock-transfected cells and cells expressing GABA<sub>B</sub>R1a alone or FLAG-HG20 (lanes 9-11). Figure 25D shows the results of immunoprecipitation with an anti-murine GABA<sub>B</sub>R1a antibody followed by immunoblotting with an anti-FLAG- 25 HG20 antibody. GABA<sub>B</sub>R1a /HG20 heterodimers are observed only in murine GABA<sub>B</sub>R1a /FLAG-HG20 co-expressing cells due to the fact that the FLAG-HG20 subunit was co-immunoprecipitated using the GABA<sub>B</sub>R1a antibodies and detected with FLAG antibody (lane 16). No FLAG-HG20 subunits are detected in mock-transfected cells or cells expressing murine GABA<sub>B</sub>R1a alone or FLAG-HG20 (lanes 30 13-15). The immunoblots shown are from 1-3 independent experiments.

Figure 26A-B shows some of the motifs in the N-termini of GABA<sub>B</sub> receptor subunits and related genes. Figure 26A shows an alignment of murine GABA<sub>B</sub>R1a (mGABA<sub>B</sub>1a; a portion of SEQ.ID.NO.:20), human GABA<sub>B</sub>R1a (hGABA<sub>B</sub>1a; a portion of SEQ.ID.NO.:21), HG20 (hGABA<sub>B</sub>2; a portion of

SEQ.ID.NO.:2), metabotropic glutamate receptor 1 (mGluR1; SEQ.ID.NO.:44), and two *E. coli* proteins (LivK (SEQ.ID.NO.:45) and LivBP (SEQ.ID.NO.:46)). Figure 26B is a schematic drawing showing the location of the various motifs in murine GABA<sub>B</sub>R1a that are expected to be involved in heterodimer formation of

5 GABA<sub>B</sub>R1a with HG20.

Figure 27 shows an expanded view of the coiled-coil region of homology between HG20 (hGABA<sub>B</sub>2; shown is a portion of SEQ.ID.NO.:2) and murine GABA<sub>B</sub>R1a (mGABA<sub>B</sub>1a; a portion of SEQ.ID.NO.:20). Also shown is the corresponding region of human GABA<sub>B</sub>R1a (hGABA<sub>B</sub>1a; a portion of

10 SEQ.ID.NO.:21).

#### DETAILED DESCRIPTION OF THE INVENTION

For the purposes of this invention:

“Substantially free from other proteins” means at least 90%, preferably 15 95%, more preferably 99%, and even more preferably 99.9%, free of other proteins. Thus, for example, an HG20 protein preparation that is substantially free from other proteins will contain, as a percent of its total protein, no more than 10%, preferably no more than 5%, more preferably no more than 1%, and even more preferably no more than 0.1%, of non-HG20 proteins. Whether a given HG20 protein preparation is 20 substantially free from other proteins can be determined by such conventional techniques of assessing protein purity as, *e.g.*, sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) combined with appropriate detection methods, *e.g.*, silver staining or immunoblotting.

“Substantially free from other nucleic acids” means at least 90%, 25 preferably 95%, more preferably 99%, and even more preferably 99.9%, free of other nucleic acids. Thus, for example, an HG20 DNA preparation that is substantially free from other nucleic acids will contain, as a percent of its total nucleic acid, no more than 10%, preferably no more than 5%, more preferably no more than 1%, and even more preferably no more than 0.1%, of non-HG20 nucleic acids. Whether a given 30 HG20 DNA preparation is substantially free from other nucleic acids can be determined by such conventional techniques of assessing nucleic acid purity as, *e.g.*, agarose gel electrophoresis combined with appropriate staining methods, *e.g.*, ethidium bromide staining, or by sequencing.

An HG20 polypeptide has “substantially the same biological activity” as native HG20 (*i.e.*, SEQ.ID.NO.:2) if that polypeptide has a  $K_d$  for a ligand that is no more than 5-fold greater than the  $K_d$  of native HG20 for the same ligand. An HG20 polypeptide also has “substantially the same biological activity” as HG20 if that polypeptide can form heterodimers with either a GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b polypeptide, thus forming a functional GABA<sub>B</sub> receptor.

“Functional GABA<sub>B</sub> receptor” refers to a heterodimer of HG20 and either GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b where the heterodimer displays a functional response when exposed to GABA agonists. Examples of functional responses are: pigment aggregation in *Xenopus* melanophores, modulation of cAMP levels, coupling to inwardly rectifying potassium channels, mediation of late inhibitory postsynaptic potentials in neurons, increase in potassium conductance, and decrease in calcium conductance. One skilled in the art would be familiar with a variety of methods of measuring the functional responses of G-protein coupled receptors such as the GABA<sub>B</sub> receptor (see, *e.g.*, Lerner, 1994, Trends Neurosci. 17:142-146 [changes in pigment distribution in melanophore cells]; Yokomizo et al., 1997, Nature 387:620-624 [changes in cAMP or calcium concentration; chemotaxis]; Howard et al., 1996, Science 273:974-977 [changes in membrane currents in *Xenopus* oocytes]; McKee et al., 1997, Mol. Endocrinol. 11:415-423 [changes in calcium concentration measured using the aequorin assay]; Offermanns & Simon, 1995, J. Biol. Chem. 270:15175, 15180 [changes in inositol phosphate levels]). Depending upon the cells in which heterodimers of HG20 and either GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b are expressed, and thus the G-proteins with which the heterodimers are coupled, certain of such methods may be appropriate for measuring the functional responses of such heterodimers. It is well within the competence of one skilled in the art to select the appropriate method of measuring functional responses for a given experimental system.

A GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b polypeptide has “substantially the same biological activity” as a native GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b polypeptide if that polypeptide has a  $K_d$  for an amino acid, amino acid analogue, GABA<sub>B</sub> receptor agonist, or GABA<sub>B</sub> receptor antagonist such as CGP71872, GABA, saclofen, (-)baclofen, or (L)-glutamic acid that is no more than 5-fold greater than the  $K_d$  of a native GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b polypeptide for the same amino acid, amino acid analogue, GABA<sub>B</sub> receptor agonist, or GABA<sub>B</sub> receptor antagonist. A GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b polypeptide also has “substantially the same biological activity” as a

native GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b polypeptide if that polypeptide can form heterodimers with an HG20 polypeptide, thus forming a functional GABA<sub>B</sub> receptor. Native GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b polypeptides include the murine GABA<sub>B</sub>R1a sequence shown as SEQ.ID.NO.:20; the rat GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b polypeptides disclosed in Kaupmann et al., 1997, Nature 386:239-246; the human GABA<sub>B</sub>R1a sequence disclosed in GenBank accession number AJ012185 (SEQ.ID.NO.:21); and the protein encoded by the DNA sequence disclosed in GenBank accession number Y11044 (SEQ.ID.NO.:23).

5 A “conservative amino acid substitution” refers to the replacement of one amino acid residue by another, chemically similar, amino acid residue. Examples of such conservative substitutions are: substitution of one hydrophobic residue (isoleucine, leucine, valine, or methionine) for another; substitution of one polar residue for another polar residue of the same charge (e.g., arginine for lysine; glutamic acid for aspartic acid).

10 15 The present invention relates to the identification and cloning of HG20, a novel G-protein coupled receptor-like protein that represents a subunit for the GABA<sub>B</sub> receptor. The present invention provides DNA encoding HG20 that is substantially free from other nucleic acids. The present invention also provides recombinant DNA molecules encoding HG20 as well as isolated DNA molecules 20 encoding HG20. Following the cloning of HG20 by the present inventors, a sequence highly similar to the sequence of HG20 was deposited in GenBank by Clark et al. (GenBank accession number AF056085), by White et al. (GenBank accession number AJ012188), and by Borowsky et al. (GenBank accession number AF074483). Two ESTs (GenBank accession number T07621, deposited June 30, 1993, and GenBank 25 accession number Z43654, deposited September 21, 1995) each contain partial sequences of HG20 cDNA.

30 The present invention provides a DNA molecule substantially free from other nucleic acids comprising the nucleotide sequence shown in Figure 1 as SEQ.ID.NO.:1. Analysis of SEQ.ID.NO.:1 revealed that it contains a long open reading frame at positions 293-3,115. Thus, the present invention also provides a DNA molecule substantially free from other nucleic acids comprising the nucleotide sequence of positions 293-3,115 of SEQ.ID.NO.:1. The present invention also provides an isolated DNA molecule comprising the nucleotide sequence of positions 293-3,115 of SEQ.ID.NO.:1.

Sequence analysis of the open reading frame of the HG20 DNA revealed that it encodes a protein of 941 amino acids with a calculated molecular weight of 104 kd and a predicted signal peptide. The predicted amino acid sequence of HG20 is 36% identical to the metabotropic GABA receptor-like sequence 5 GABA<sub>B</sub>R1a described in Kaupmann (see above) throughout the entire sequence, and thus HG20 most likely represents a novel metabotropic GABA receptor or receptor subunit. *In situ* hybridization showed that HG20 RNA is highly expressed in the cortex, thalamus, hippocampus, and cerebellum of the brain, showing overlapping distribution with GABA<sub>B</sub>R1a RNA as judged by *in situ* hybridization as well as with 10 the expression of GABA<sub>B</sub> receptors as judged by pharmacological studies. HG20 RNA exhibits restricted distribution in the periphery, with low abundance of the 6.5 kb RNA in the heart, spleen, and pancreas and high levels in the adrenal gland. HG20 recombinantly expressed in COS-1 cells showed no specific binding for 15 [3H](+)baclofen, and when expressed in *Xenopus* oocyte and *Xenopus* melanophore functional assays, showed no activity to GABA, (-)baclofen, and glutamic acid.

The novel DNA sequences of the present invention encoding HG20, in whole or in part, can be linked with other DNA sequences, *i.e.*, DNA sequences to which HG20 is not naturally linked, to form “recombinant DNA molecules” containing HG20. Such other sequences can include DNA sequences that control 20 transcription or translation such as, *e.g.*, translation initiation sequences, promoters for RNA polymerase II, transcription or translation termination sequences, enhancer sequences, sequences that control replication in microorganisms, or that confer antibiotic resistance. The novel DNA sequences of the present invention can be inserted into vectors such as plasmids, cosmids, viral vectors, or yeast artificial 25 chromosomes.

The present invention also includes isolated forms of DNA encoding HG20. By “isolated DNA encoding HG20” is meant DNA encoding HG20 that has been isolated from a natural source or produced by recombinant means. Use of the term “isolated” indicates that DNA encoding HG20 is not present in its normal 30 cellular environment. Thus, an isolated DNA encoding HG20 may be in a cell-free solution or placed in a different cellular environment from that in which it occurs naturally. The term isolated does not imply that isolated DNA encoding HG20 is the only DNA present, but instead means that isolated DNA encoding HG20 is at least 95% free of non-nucleic acid material (*e.g.*, proteins, lipids, carbohydrates) naturally

associated with the DNA encoding HG20. Thus, DNA encoding HG20 that is expressed in bacteria or even in eukaryotic cells which do not naturally (*i.e.*, without human intervention) contain it through recombinant means is “isolated DNA encoding HG20.”

5         Included in the present invention are DNA sequences that hybridize to SEQ.ID.NO.:1 under stringent conditions. By way of example, and not limitation, a procedure using conditions of high stringency is as follows: Prehybridization of filters containing DNA is carried out for 2 hr. to overnight at 65°C in buffer composed of 6X SSC, 5X Denhardt’s solution, and 100  $\mu$ g/ml denatured salmon sperm DNA.

10        Filters are hybridized for 12 to 48 hrs at 65°C in prehybridization mixture containing 100  $\mu$ g/ml denatured salmon sperm DNA and 5-20 X  $10^6$  cpm of  $^{32}$ P-labeled probe. Washing of filters is done at 37°C for 1 hr in a solution containing 2X SSC, 0.1% SDS. This is followed by a wash in 0.1X SSC, 0.1% SDS at 50°C for 45 min. before autoradiography.

15        Other procedures using conditions of high stringency would include either a hybridization carried out in 5XSSC, 5X Denhardt’s solution, 50% formamide at 42°C for 12 to 48 hours or a washing step carried out in 0.2X SSPE, 0.2% SDS at 65°C for 30 to 60 minutes.

20        Reagents mentioned in the foregoing procedures for carrying out high stringency hybridization are well known in the art. Details of the composition of these reagents can be found in, *e.g.*, Sambrook, Fritsch, and Maniatis, 1989, Molecular Cloning: A Laboratory Manual, second edition, Cold Spring Harbor Laboratory Press. In addition to the foregoing, other conditions of high stringency which may be used are well known in the art.

25        Another aspect of the present invention includes host cells that have been engineered to contain and/or express DNA sequences encoding HG20. Such recombinant host cells can be cultured under suitable conditions to produce HG20. An expression vector containing DNA encoding HG20 can be used for expression of HG20 in a recombinant host cell. Recombinant host cells may be prokaryotic or 30 eukaryotic, including but not limited to, bacteria such as *E. coli*, fungal cells such as yeast, mammalian cells including, but not limited to, cell lines of human, bovine, porcine, monkey and rodent origin, and insect cells including but not limited to *Drosophila* and silkworm derived cell lines. Cell lines derived from mammalian species which are suitable for recombinant expression of HG20 and which are

commercially available, include but are not limited to, L cells L-M(TK<sup>-</sup>) (ATCC CCL 1.3), L cells L-M (ATCC CCL 1.2), HEK293 (ATCC CRL 1573), Raji (ATCC CCL 86), CV-1 (ATCC CCL 70), COS-1 (ATCC CRL 1650), COS-7 (ATCC CRL 1651), CHO-K1 (ATCC CCL 61), 3T3 (ATCC CCL 92), NIH/3T3 (ATCC CRL 1658),

5 HeLa (ATCC CCL 2), C127I (ATCC CRL 1616), BS-C-1 (ATCC CCL 26), MRC-5 (ATCC CCL 171), *Xenopus* melanophores, and *Xenopus* oocytes. In particular embodiments, the recombinant cells expressing HG20 protein co-express a GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b protein, thus forming a functional GABA<sub>B</sub> receptor comprising a heterodimer of HG20 and either GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b. In

10 particular embodiments, the recombinant cells have been transfected with expression vectors that direct the expression of HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b.

Cells that are particularly suitable for expression of the HG20 protein are melanophore pigment cells from *Xenopus laevis*. Such melanophore pigment cells can be used for functional assays that employ recombinant expression of HG20 in a manner similar to the use of such melanophore pigment cells for the functional assay of other recombinant GPCRs (Graminski et al., 1993, *J. Biol. Chem.* 268:5957-5964; Lerner, 1994, *Trends Neurosci.* 17:142-146; Potenza & Lerner, 1992, *Pigment Cell Res.* 5:372-378; Potenza et al., 1992, *Anal. Biochem.* 206:315-322). Especially preferred are *Xenopus* melanophore pigment cells co-expressing HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b, in which HG20 has formed a heterodimer with GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b, thus forming a functional GABA<sub>B</sub> receptor. The presence of functional GABA<sub>B</sub> receptors in such cells can be determined by the use of assays such as the pigment aggregation assay described herein. Other assays that reflect a decrease in cAMP levels mediated by exposure to GABA or other agonists of GABA<sub>B</sub> receptors would also be suitable.

Also preferred are stably or transiently transfected HEK293 cells co-expressing HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b, in which HG20 has formed a heterodimer with GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b, thus forming a functional GABA<sub>B</sub> receptor. The presence of functional GABA<sub>B</sub> receptors in such cells can be determined by the use of assays such as those that measure cAMP levels as described herein.

Also preferred are *Xenopus* oocytes co-expressing HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b, in which HG20 has formed a heterodimer with GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b, thus forming a functional GABA<sub>B</sub> receptor. The

presence of functional GABA<sub>B</sub> receptors in such cells can be determined by the use of assays that measure coupling of functional GABA<sub>B</sub> receptors comprising heterodimers of HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b to inwardly rectifying potassium channels (especially the Kir3 family).

5 In order to produce the above-described cells co-expressing HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b, expression vectors comprising DNA encoding HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b can be transfected into the cells. HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b can be transfected separately, each on its own expression vector, or, alternatively, a single expression vector encoding both HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b can be used.

10 A variety of mammalian expression vectors can be used to express recombinant HG20, GABA<sub>B</sub>R1a, or GABA<sub>B</sub>R1b in mammalian cells. Commercially available mammalian expression vectors which are suitable include, but are not limited to, pMC1neo (Stratagene), pSG5 (Stratagene), pcDNAI and 15 pcDNAIamp, pcDNA3, pcDNA3.1, pCR3.1 (Invitrogen), EBO-pSV2-neo (ATCC 37593), pBPV-1(8-2) (ATCC 37110), pdBPV-MMTneo(342-12) (ATCC 37224), pRSVgpt (ATCC 37199), pRSVneo (ATCC 37198), pSV2-dhfr (ATCC 37146), and the PT7TS oocyte expression vector (or similar expression vectors containing the globin 5' UTR and the globin 3' UTR). The choice of vector will depend upon cell 20 type used, level of expression desired, and the like. Following expression in recombinant cells, HG20, GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, or heterodimers of HG20 and either GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b can be purified to a level that is substantially free from other proteins by conventional techniques, *e.g.*, salt fractionation, ion exchange chromatography, size exclusion chromatography, hydroxylapatite adsorption 25 chromatography, hydrophobic interaction chromatography, and preparative gel electrophoresis. Also, membrane preparations comprising HG20, GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, or heterodimers of HG20 and either GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b can be prepared. Especially preferred are membrane preparations that comprise heterodimers of HG20 and either GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b in which the 30 heterodimers represent functional GABA<sub>B</sub> receptors.

The present invention includes a method of producing HG20 protein comprising:

(a) transfecting a host cell with an expression vector comprising DNA that encodes an HG20 protein;

(b) growing the host cells under conditions such that HG20 protein is produced; and

(c) recovering HG20 protein from the host cells.

In particular embodiments, the method of recovering HG20 protein 5 involves obtaining membrane preparations that contain HG20 protein from the host cells. In particular embodiments, such membrane preparations contain heterodimers of HG20 protein and GABABR1a or GABABR1b protein that form functional GABAB receptors.

The present invention includes a method of expressing a truncated 10 HG20 protein comprising:

- (a) transfecting a host cell with an expression vector comprising DNA that encodes an HG20 protein that has been truncated at the amino or carboxyl terminus;
- (b) culturing the transfected cells of step (a) under conditions such 15 that the truncated HG20 protein is expressed.

Truncated HG20 proteins are those HG20 proteins in which contiguous portions of the N terminus or C terminus have been removed. For example, positions 52-941 of SEQ.ID.NO.:2 represents a truncated HG20 protein. Truncated HG20 proteins may be fused in frame to non-HG20 amino acid sequences, 20 as, *e.g.*, in the FLAG-HG20 construct described herein.

The present invention includes a method of producing functional GABAB receptors in cells comprising:

- (a) transfecting cells with:
  - (1) an expression vector that directs the expression of 25 HG20 in the cells; and
  - (2) an expression vector that directs the expression of GABABR1a or GABABR1b in the cells;
- (b) culturing the cells under conditions such that heterodimers of HG20 and GABABR1a or GABABR1b are formed where the heterodimers constitute 30 functional GABAB receptors.

In particular embodiments of the above methods, the cells are eukaryotic cells. In other embodiments, the cells are mammalian cells. In still other embodiments, the cells are COS cells, *e.g.*, COS-7 cells (ATCC CRL 1651) or COS-

1 cells (ATCC CRL 1650); HEK293 cells (ATCC CRL 1573); or *Xenopus* melanophores.

5 In particular embodiments, the HG20 protein comprises the amino acid sequence shown in SEQ.ID.NO.:2. In particular embodiments, the HG20 protein is a truncated HG20 protein. In particular embodiments, the truncated HG20 protein comprises amino acids 52-941 of SEQ.ID.NO.:2. In particular embodiments, the truncated HG20 protein is a chimeric HG20 protein.

10 The present invention includes HG20 protein substantially free from other proteins. The amino acid sequence of the full-length HG20 protein is shown in Figure 2 as SEQ.ID.NO.:2. Thus, the present invention includes polypeptides comprising HG20 protein substantially free from other proteins where the polypeptides comprise the amino acid sequence SEQ.ID.NO.:2. The present invention also includes polypeptides comprising HG20 proteins lacking a signal sequence. Examples of amino acid sequences of HG20 proteins lacking a signal 15 sequence are:

20 Positions 9-941 of SEQ.ID.NO.:2;  
Positions 35-941 of SEQ.ID.NO.:2;  
Positions 36-941 of SEQ.ID.NO.:2;  
Positions 38-941 of SEQ.ID.NO.:2;  
Positions 39-941 of SEQ.ID.NO.:2;  
25 Positions 42-941 of SEQ.ID.NO.:2;  
Positions 44-941 of SEQ.ID.NO.:2;  
Positions 46-941 of SEQ.ID.NO.:2;  
Positions 52-941 of SEQ.ID.NO.:2; and  
Positions 57-941 of SEQ.ID.NO.:2.

25 The present invention also includes DNA encoding the above-described HG20 proteins lacking a signal sequence. Thus, *e.g.*, the present invention includes a DNA molecule comprising a nucleotide sequence selected from the group consisting of:

30 Positions 293-3,115 of SEQ.ID.NO.:1;  
Positions 317-3,115 of SEQ.ID.NO.:1;  
Positions 395-3,115 of SEQ.ID.NO.:1;  
Positions 398-3,115 of SEQ.ID.NO.:1;  
Positions 404-3,115 of SEQ.ID.NO.:1;

Positions 407-3,115 of SEQ.ID.NO.:1;

Positions 416-3,115 of SEQ.ID.NO.:1;

Positions 422-3,115 of SEQ.ID.NO.:1;

Positions 428-3,115 of SEQ.ID.NO.:1;

Positions 446-3,115 of SEQ.ID.NO.:1; and

Positions 461-3,115 of SEQ.ID.NO.:1.

As with many receptor proteins, it is possible to modify many of the amino acids of HG20, particularly those which are not found in the ligand binding domain, and still retain substantially the same biological activity as the original protein. Thus this invention includes modified HG20 polypeptides which have amino acid deletions, additions, or substitutions but that still retain substantially the same biological activity as native HG20. It is generally accepted that single amino acid substitutions do not usually alter the biological activity of a protein (see, e.g., Molecular Biology of the Gene, Watson et al., 1987, Fourth Ed., The Benjamin/Cummings Publishing Co., Inc., page 226; and Cunningham & Wells, 1989, Science 244:1081-1085). Accordingly, the present invention includes polypeptides where one amino acid substitution has been made in SEQ.ID.NO.:2 or in one of the HG20 polypeptides lacking a signal sequence listed above, wherein the polypeptides still retain substantially the same biological activity as native HG20. The present invention also includes polypeptides where two or more amino acid substitutions have been made in SEQ.ID.NO.:2 or in one of the HG20 polypeptides lacking a signal sequence listed above, wherein the polypeptides still retain substantially the same biological activity as native HG20. In particular, the present invention includes embodiments where the above-described substitutions are conservative substitutions. In particular, the present invention includes embodiments where the above-described substitutions do not occur in the ligand-binding domain of HG20. In particular, the present invention includes embodiments where amino acid changes have been made in the positions of HG20 where the amino acid sequence of HG20 differs from the amino acid sequence of GABA<sub>B</sub>R1b (see Figure 8).

The present invention also includes C-terminal truncated forms of HG20, particularly those which encompass the extracellular portion of the receptor, but lack the intracellular signaling portion of the receptor. Such truncated receptors are useful in various binding assays described herein, for crystallization studies, and for structure-activity-relationship studies. Accordingly, the present invention includes

an HG20 protein substantially free from other proteins having the amino acid sequence of positions 1-480 of SEQ.ID.NO.:2.

O'Hara et al., 1993, *Neuron* 11:41-52 (O'Hara) reported that the amino terminal domains of several metabotropic glutamate receptors showed amino acid sequence similarities to the amino termini of several bacterial periplasmic binding proteins. O'Hara used this similarity to predict, and then experimentally confirm, that these amino terminal domains correspond to the location of the ligand binding domains of these metabotropic glutamate receptors.

The present inventors have discovered a region of amino acid sequence in the N-terminal domain of HG20 that is similar to the amino acid sequence of the bacterial periplasmic binding protein Leucine, Isoleucine, Valine (Alanine and Threonine) Binding Protein (LIVAT-BP) of *Pseudomonas aeruginosa*. See Figure 6. The region shown is about 25% identical between the two proteins. This is above the maximum identity of 17% reported by O'Hara between any one metabotropic glutamate receptor and any one periplasmic binding protein and indicates that the region of HG20 depicted is highly likely to contain the ligand binding domain.

Accordingly, the present invention includes a polypeptide representing the ligand binding domain of HG20 that includes amino acids 63-259 of SEQ.ID.NO.:2. Also provided are chimeric proteins comprising amino acids 63-259 of SEQ.ID.NO.:2.

Romano et al., 1996, *J. Biol. Chem.* 271:28612-28616 demonstrated that metabotropic glutamate receptors are often found as homodimers formed by an intermolecular disulfide bond. The location of the cysteines responsible for the disulfide bond was found to be in the amino terminal 17kD of the receptors. Transmembrane interactions may also contribute to functional GABA<sub>B</sub> receptor dimer formation, as previously reported for the dopamine D2 receptor and  $\beta$ 2-adrenergic receptor (Ng et al., 1996, *Biochem. Biophys. Res. Comm.* 227:200-204; Hebert et al., 1996, *J. Biol. Chem.* 271, 16384-16392). Accordingly, the present invention includes dimers of HG20 proteins. In particular embodiments, the HG20 protein has an amino acid selected from the group consisting of:

SEQ.ID.NO.:2;  
Positions 9-941 of SEQ.ID.NO.:2;  
Positions 35-941 of SEQ.ID.NO.:2;  
Positions 36-941 of SEQ.ID.NO.:2;  
5 Positions 38-941 of SEQ.ID.NO.:2;  
Positions 39-941 of SEQ.ID.NO.:2;  
Positions 42-941 of SEQ.ID.NO.:2;  
Positions 44-941 of SEQ.ID.NO.:2;  
Positions 46-941 of SEQ.ID.NO.:2;  
10 Positions 52-941 of SEQ.ID.NO.:2;  
Positions 57-941 of SEQ.ID.NO.:2; and  
Positions 1-480 of SEQ.ID.NO.:2.

It has been found that, in some cases, membrane spanning regions of receptor proteins can be used to inhibit receptor function (Ng et al., 1996, Biochem. 15 Biophys. Res. Comm. 227:200-204; Hebert et al., 1996, J. Biol. Chem. 271, 16384-16392; Loftis et al., Oncogene 8:2813-2820). Accordingly, the present invention provides peptides derived from the seven membrane spanning regions of HG20 and their use to inhibit HG20 or GABA<sub>B</sub> receptor function. Such peptides can include the whole or parts of the membrane spanning domains.

20 The present invention also includes isolated forms of HG20 proteins. By “isolated HG20 protein” is meant HG20 protein that has been isolated from a natural source or produced by recombinant means. Use of the term “isolated” indicates that HG20 protein is not present in its normal cellular environment. Thus, an isolated HG20 protein may be in a cell-free solution or placed in a different 25 cellular environment from that in which it occurs naturally. The term isolated does not imply that an isolated HG20 protein is the only protein present, but instead means that an isolated HG20 protein is at least 95% free of non-amino acid material (e.g., nucleic acids, lipids, carbohydrates) naturally associated with the HG20 protein. Thus, an HG20 protein that is expressed through recombinant means in bacteria or 30 even in eukaryotic cells which do not naturally (i.e., without human intervention) express it is an “isolated HG20 protein.”

The present invention also includes chimeric HG20 proteins. By chimeric HG20 protein is meant a contiguous polypeptide sequence of HG20 fused in frame to a polypeptide sequence of a non-HG20 protein. For example, the N-terminal

domain and seven transmembrane spanning domains of HG20 fused at the C-terminus in frame to a G protein would be a chimeric HG20 protein. Another example of a chimeric HG20 protein would be a polypeptide comprising the FLAG epitope fused in frame at the amino terminus of amino acids 52-941 of SEQ.ID.NO.:2.

5 The present invention also includes HG20 proteins that are in the form of multimeric structures, *e.g.*, dimers. Such multimers of other metabotropic G-protein coupled receptors are known (Hebert et al., 1996, *J. Biol. Chem.* 271, 16384-16392; Ng et al., 1996, *Biochem. Biophys. Res. Comm.* 227, 200-204; Romano et al., 1996, *J. Biol. Chem.* 271, 28612-28616).

10 Preferred forms of dimers of HG20 are heterodimers comprising HG20 and other G-protein coupled receptors (GPCRs). Such GPCRs could be, *e.g.*, other subunits of GABA<sub>B</sub> receptors, proteins from *C. elegans* showing homology to HG20 (see Figure 24), or human GPCRs that are homologs of the *C. elegans* proteins. Particularly preferred forms of heterodimers are heterodimers of HG20 and either 15 GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b. It has been found by the present inventors that such heterodimers exhibit functional properties of GABA<sub>B</sub> receptors while monomers or homodimers of HG20, GABA<sub>B</sub>R1a, or GABA<sub>B</sub>R1b do not exhibit functional properties. Another likely heterodimer partner for HG20 is the protein corresponding to the sequence deposited in GenBank at accession number 3776096.

20 The strongest evidence that functional GABA<sub>B</sub> receptors require both HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b comes from studies demonstrating that co-transfection and co-expression of both HG20 and either GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b is necessary in order for the detection of GABA<sub>B</sub> receptor functional responses. Transfection and expression of HG20, GABA<sub>B</sub>R1a, or GABA<sub>B</sub>R1b alone does not 25 lead to the production of functional GABA<sub>B</sub> receptors.

For example, in *Xenopus* melanophores co-expressing HG20 and GABA<sub>B</sub>R1a, but not in melanophores expressing HG20 or GABA<sub>B</sub>R1a alone, or in mock transfected melanophores, GABA mediated a dose-dependent pigment aggregation response that could be inhibited with the GABA<sub>B</sub> receptor specific 30 CGP71872 antagonist. This pigment aggregation response is associated with a decrease in intracellular cAMP levels. Such a decrease has been confirmed in HEK293 cells. Also, co-expression of HG20 and GABA<sub>B</sub>R1a in *Xenopus* oocytes resulted in the stimulation of inwardly rectifying potassium currents (Kirs). Native

functional GABA<sub>B</sub> receptors have been reported to couple to Kirs (Misgeld et al., 1995, *Prog. Neurobiol.* 46:423-462).

Consistent with the need for both HG20 and GABA<sub>B</sub>R1a for detection of functional GABA<sub>B</sub> receptors in transfected cells, the present inventors have 5 demonstrated that HG20 and GABA<sub>B</sub>R1a form heterodimers by immunoprecipitation of HG20 followed by immunoblotting with a GABA<sub>B</sub>R1a antibody.

That a functional GABA<sub>B</sub> receptor requires both HG20 and either GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b is also suggested by the observation that GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b, recombinantly expressed in the absence of HG20, binds ligand with 10 much reduced affinity compared to the affinity of native GABA<sub>B</sub> receptors. Also, characterization of the tissue distribution of each of the receptors by *in situ* hybridization histochemistry in rat brain revealed co-localization of HG20 and GABA<sub>B</sub>R1a transcripts in many brain regions, including cortex, at both the regional and cellular levels.

15 The *Xenopus* melanophore pigment aggregation/dispersion assay has been shown to be highly suitable for monitoring agonist activation of Gi-, Gq-, and Gs-coupled receptors (Potenza et al., 1992, *Anal. Biochem.* 206:315-322; Lerner, 1994, *Trends Neurosci.* 17:142-146). Agonist activation of Gi-coupled receptors expressed in melanophores results in pigment aggregation via a reduction in 20 intracellular cAMP levels, whereas activation of Gs- and Gq-coupled receptors results in pigment dispersion via elevations in intracellular cAMP and calcium levels, respectively. Melanophores transfected separately with either GABA<sub>B</sub>R1a or HG20 showed no pigment aggregation or dispersion response following treatment with up to 1 mM concentrations of (L)-glutamic acid, GABA, or prototypic GABAergic 25 agonists: (-)baclofen, 3-aminopropyl-(methyl)phosphonic acid, cis-4-aminocrotonic acid, piperidine-4-sulfonic acid (data not shown). Similarly, both receptors failed to couple to K<sup>+</sup> channels in *Xenopus* oocytes under patch-clamp conditions when transfected separately (data not shown). However, in melanophores transiently co-transfected with GABA<sub>B</sub>R1a and HG20, GABA mediated a dose-dependent 30 aggregation response with an IC<sub>50</sub> value of 3-7 μM (n=3). This aggregation was absent in mock-transfected cells and in cells transfected with GABA<sub>B</sub>R1a or HG20 alone (Figure 11). The GABA-mediated activity represented 42-56% (n=3) of a control cannabinoid receptor subtype 2 response (Figure 11, inset), and could be inhibited by the CGP71872 antagonist (n=3), indicating it was GABA<sub>B</sub> receptor

specific (Figure 11). GABA<sub>B</sub>R1a was expressed by subcloning full-length GABA<sub>B</sub>R1a into the NheI-NotI site of pcDNA3.1 or pCIneo; HG20 was expressed as a FLAG-HG20 chimeric protein. See Examples 11 and 20 for further experimental details of expression vectors used, transfection conditions, assay conditions, *etc.* for the above-described co-expression studies.

The functional data arising from co-expression of GABA<sub>B</sub>R1a and HG20 receptors were confirmed in HEK293 cells. HEK293 cells transfected with and stably expressing GABA<sub>B</sub>R1a and HG20 were selected based on expression of receptor message as determined by dot blot analyses. In cell lines stably expressing the individual receptors, we observed small and inconsistent responses in assays to examine agonist-mediated modulation of cAMP synthesis. However, transient transfection of HEK293 cells stably expressing GABA<sub>B</sub>R1a (rgb1a-50) with an HG20 expression plasmid and transient transfection of HEK293 cells stably expressing HG20 (hgb2-42) with a GABA<sub>B</sub>R1a expression plasmid significantly enhanced the ability of baclofen and GABA to inhibit forskolin-stimulated cAMP synthesis. Rgb1a-50 cells transfected with HG20 exhibited a 28% reduction in forskolin-stimulated cAMP synthesis with 30  $\mu$ M baclofen and a 40% decrease with 30  $\mu$ M GABA plus 100  $\mu$ M aminoxyacetic acid (AOAA; a GABA transaminase inhibitor) and 100  $\mu$ M nipecotic acid (a GABA uptake inhibitor) (Figure 12B). A 34% reduction in forskolin-stimulated cAMP synthesis was observed for hgb2-42 cells transfected with GABA<sub>B</sub>R1a treated with baclofen and a 43% decrease was observed for GABA plus AOAA and nipecotic acid (Figure 12B). While inhibition of cAMP synthesis was sometimes observed with rgb1a-50 cells transfected with GABA<sub>B</sub>R1a and hgb2-42 cells transfected with HG20, these effects were small and inconsistent (0-20% inhibition; Figure 12B). Neither baclofen nor GABA plus AOAA and nipecotic acid in the absence of forskolin had any affect on cAMP synthesis (Figure 12B). In addition, wild-type HEK293 cells did not exhibit baclofen- or GABA-mediated inhibition of forskolin-stimulated cAMP synthesis (Figure 12B). These data demonstrate that the functional GABA<sub>B</sub> receptor requires both GABA<sub>B</sub>R1a and HG20. For experimental details of these studies in HEK293 cells, see Example 12.

Co-expression of the GABA<sub>B</sub>R1a and HG20 with the inwardly rectifying potassium channels Kir 3.1/3.2 in *Xenopus* oocytes resulted in a significant stimulation of inwardly rectifying potassium current (Kir) in response to GABA [301

+/- 20.6 %, (n=3) increase over control current] measured at -80 mV which could subsequently be washed out with control solution (Figure 13). Modulation of Kir 3.1/3.2 was not seen in oocytes expressing GABA<sub>B</sub>R1a or HG20 individually, even in the presence of Gi $\alpha$ 1 (Figure 13). See Example 21 for details.

5 To determine whether receptor intermolecular interactions accounted for the functional activity that was observed following the co-expression of recombinant GABA<sub>B</sub>R1a and HG20, membranes from cells co-expressing GABA<sub>B</sub>R1a and HG20 or the individual proteins were first immunoprecipitated using anti-FLAG antibodies (to detect the recombinant FLAG-HG20 chimeric 10 proteins) followed by immunoblotting with a GABA<sub>B</sub>R1a-specific antibody. As seen in Figure 14, lanes 1-3, no GABA<sub>B</sub>R1a immunoreactivity was detected in samples prepared from mock vector transfected cells, FLAG-HG20 alone expressing cells, and GABA<sub>B</sub>R1a alone expressing cells immunoprecipitated with the FLAG-antibody. 15 Since immunoreactive species were detected only in cells co-expressing HG20 and GABA<sub>B</sub>R1a, this experiment demonstrates that HG20 and GABA<sub>B</sub>R1a can only be co-immunoprecipitated as part of a complex (Figure 14, lane 4). Based on the predicted molecular mass of a heterodimer of HG20 and GABA<sub>B</sub>R1a, the ~250+ and ~130 kDa species may represent a heterodimer and GABA<sub>B</sub>R1a monomers, respectively. The stability of the HG20/GABA<sub>B</sub>R1a heterodimer in denaturing and 20 reducing conditions suggests that SDS-stable transmembrane interactions form the heterodimer, as reported previously for  $\beta$ 2 adrenergic and dopamine D2 receptors (Ng et al., 1996, Biochem. Biophys. Res. Comm. 227:200-204; Hebert et al., 1996, J. Biol. Chem. 271, 16384-16392). The monomer might result from partial disruption, 25 subsequent to immunoprecipitation, of N-terminal Sushi repeats, C-terminal alpha-helical interacting domains (*e.g.*, coiled-coils) present in HG20 and GABA<sub>B</sub>R1a subunits, transmembrane interactions, or disulfide bonds that contribute to forming the heterodimer.

Particular examples of such regions likely to be involved in forming the heterodimer are shown in Figure 23. Regions such as those shown in Figure 23, 30 as well as polypeptides comprising such regions are expected to be useful for the purpose of modulating the formation of heterodimers involving HG20 and thus controlling GABA<sub>B</sub> receptor activity. Accordingly, the present invention includes polypeptides comprising the coiled-coil domains of HG20, GABA<sub>B</sub>R1a, and GABA<sub>B</sub>R1b. In particular, the present invention includes polypeptides comprising an

amino acid sequence selected from the group consisting of: positions 756-829 of SEQ.ID.NO.:2; positions 779-814 of SEQ.ID.NO.:2; positions 886-949 of SEQ.ID.NO.:21; and positions 889-934 of SEQ.ID.NO.:21; where the polypeptides do not contain other contiguous amino acid sequences longer than 5 amino acids from a GABA<sub>B</sub> receptor subunit. The present invention also includes heterodimers of such polypeptides. In more general terms, the present invention includes comprising a coiled-coil domain from a first GABA<sub>B</sub> receptor subunit and no other contiguous amino acid sequences longer than 5 amino acids from the first GABA<sub>B</sub> receptor subunit where the coiled-coil domain is present in the C-terminus of the first GABA<sub>B</sub> receptor subunit and mediates heterodimerization of the first GABA<sub>B</sub> receptor subunit with a second GABA<sub>B</sub> receptor subunit.

In addition to the coiled-coil domains discussed above, a variety of regions of HG20 and GABA<sub>B</sub>R1a are expected to be important for heterodimer formation. Motif analysis of the N-terminus of murine GABA<sub>B</sub>R1a revealed seven consensus N-linked glycosylation sites and three putative short consensus repeats (SCRs) of ~60 amino acids each: amino acids 27-96 and amino acids 102-157 (GABA<sub>B</sub>R1a specific), and amino acids 183-245 (common to GABA<sub>B</sub>R1b (Kaupmann et al., 1997, Nature 386:239-246) and HG20 (Jones et al., 1998, Nature 396:674-679; White et al., 1998, Nature 396:679-682; Kaupmann et al., 1998, Nature 396:683-687; Kuner et al., 1999, Science 283:74-77) not described previously (Figure 26A-B). Since SCRs are known to play important roles in protein-protein interactions in a wide variety of complement proteins, adhesion proteins, and selections (Chou and Heinrikson, 1997, J. Protein Chem. 16:765-773; Perkins et al., 1998, Biochemistry 27:4004-4012), of which the latter shows weak amino acid identity to murine GABA<sub>B</sub>R1a, these SCRs, together with the coiled-coil domains discussed above in the carboxyl tails of GABA<sub>B</sub>R1a and HG20 (Figure 23), are expected to be involved in the heterodimerization of GABA<sub>B</sub>R1a and HG20.

Therefore, the present invention includes a polypeptide comprising an SCR domain from a first GABA<sub>B</sub> receptor subunit and no other contiguous amino acid sequences longer than 5 amino acids from the first GABA<sub>B</sub> receptor subunit where the SCR domain is present in the N-terminus of the first GABA<sub>B</sub> receptor subunit and mediates heterodimerization of the first GABA<sub>B</sub> receptor subunit with a second GABA<sub>B</sub> receptor subunit. In particular embodiments, the SCR is selected from the group consisting of: positions 27-96 of SEQ.ID.NO.:20; positions 102-157

of SEQ.ID.NO.:20; positions 183-245 of SEQ.ID.NO.:20; positions 28-97 of SEQ.ID.NO.:21; positions 103-158 of SEQ.ID.NO.:21; positions 184-246 of SEQ.ID.NO.:21; positions 4-22 of SEQ.ID.NO.:2; positions 23-49 of SEQ.ID.NO.:2; and positions 72-135 of SEQ.ID.NO.:2.

5 As in the metabotropic glutamate receptors (mGLURs), the second intracellular loop of murine GABA<sub>B</sub>R1a is rich in basic amino acids which may play a role in G-protein-interactions (reviewed by Pin and Duvoisin, 1995, *Neuropharmacology* 34:1-26), and, as in the mGLURs, the carboxyl tail of murine GABA<sub>B</sub>R1a contains a PDZ protein-interacting module (serine-arginine-valine, 10 amino acids 953-955) which has been shown for mGLURs to play an important role in the interactions among the signaling components of synaptic junctions (Brakeman et al. 1997, *Nature* 386:284-288). The murine GABA<sub>B</sub>R1a receptor also contains potential protein kinase C and casein kinase II recognition sites predicted using ProSearch (Kolakowski et al., 1992, *Biotechniques* 13:919-921).

15 The present invention also relates to the identification and cloning of the murine GABA<sub>B</sub>R1a receptor, the murine ortholog of the rat GABA<sub>B</sub>R1a receptor described in Kaupmann et al., 1997, *Nature* 386:239-246 (Kaupmann). The present invention provides DNA encoding murine GABA<sub>B</sub>R1a that is substantially free from other nucleic acids. The present invention also provides recombinant DNA molecules 20 encoding murine GABA<sub>B</sub>R1a.

25 The present invention provides a DNA molecule encoding murine GABA<sub>B</sub>R1a that is substantially free from other nucleic acids and comprises the nucleotide sequence shown in Figure 15 as SEQ.ID.NO.:19. The open reading frame of SEQ.ID.NO.:19, encoding mouse GABA<sub>B</sub>R1a protein, is positions 1-2,880, with positions 2,881-2,883 representing a stop codon. Thus, the present invention also provides a DNA molecule substantially free from other nucleic acids comprising the nucleotide sequence of positions 1-2,880 of SEQ.ID.NO.:19.

30 Sequence analysis of the open reading frame of the murine GABA<sub>B</sub>R1a DNA revealed that it encodes a mature protein (*i.e.*, lacking a signal sequence) of 942 amino acids with a predicted molecular weight of 106.5 kDa that is 99% identical to rat GABA<sub>B</sub>R1a (described in Kaupmann), with only six amino acid changes overall. Murine GABA<sub>B</sub>R1a protein shares 31% overall amino acid identity to HG20.

CGP71872 is a photoaffinity ligand specific for GABA<sub>B</sub>R1a receptors ( $K_d = 1.0 \pm 0.2$  nM) that can be cross-linked to rat GABA<sub>B</sub>R1a (Kaupmann et al., 1997, *Nature* 386:239-246). In crude membranes prepared from COS-7 cells transiently transfected with murine GABA<sub>B</sub>R1a, [<sup>125</sup>I]CGP71872 photolabelled a major band at ~130 kDa representing the mature (presumably glycosylated) protein and an additional band at approximately twice that molecular weight, possibly representing dimers (Figure 9). Ligand-binding species could also be detected with affinity purified GABA<sub>B</sub>R1a antibodies 1713.1 (raised against the peptide acetyl-DVNSRRDILPDYELKLC-amide; a portion of SEQ.ID.NO.:20) and 1713.2 (raised against the peptide acetyl-CATLHNPTRVKLFEK-amide; a portion of SEQ.ID.NO.:20) (Figure 9). In contrast, FLAG-tagged HG20 protein did not bind the high-affinity CGP71872 ligand, although expression of the protein was confirmed by immunoblot analysis (Figure 9).

Displacement of [<sup>125</sup>I]CGP71872 binding to recombinant murine GABA<sub>B</sub>R1a was in the appropriate rank order of potency for GABAergic ligands: CGP71872 > SKF-97541 (3-aminopropyl(methyl)-phosphinic acid) > GABA > (-)baclofen > saclofen > (L)-glutamic acid.. Interestingly, recombinant rat GABA<sub>B</sub>R1a exhibits 10-25 fold lower affinity for agonists than native GABA<sub>B</sub> receptors in brain (Kaupmann et al., 1997, *Nature* 386:239). Although the reason for this discrepancy remains unclear, a recent report indicated that recombinant GABA<sub>B</sub>R1a may require additional cellular components for functional targeting to the plasma membrane (Couve et al., 1998, *J. Biol. Chem.* 273:26361-26367). Thus, GABA<sub>B</sub>R1a alone, without such additional components, might be expected to exhibit somewhat altered ligand binding characteristics.

In the binding experiments discussed above using GABA<sub>B</sub>R1a alone, surprisingly, dose-dependent displacement was not detected for (+)baclofen, and the affinities of agonists (GABA, SKF-97541, and (-)baclofen) and partial agonists ((+)baclofen, saclofen, (L)-glutamic acid) but not the affinity of antagonist (CGP71872) for the recombinant GABA<sub>B</sub>R1a were markedly lower compared to native receptors in rat brain (Table 1). Agonist affinities of co-expressed HG20 and GABA<sub>B</sub>R1a were examined in membranes prepared from cells co-expressing GABA<sub>B</sub>R1a and FLAG-tagged HG20. Competition of [<sup>125</sup>I]CGP71872 binding in these membranes showed recovery of high-affinity ligand binding comparable to native receptors in rat brain (Table 1). The simplest explanation for these results is

that the high-affinity agonist binding pocket may comprise interactions between the N-terminal domains of HG20 and GABA<sub>B</sub>R1a that form the heterodimer.

Table 1

5

Ligand	rat cortex*	gb1a	gb1a/gb2
CGP71872	0.5 nM	0.52 - 0.67 nM	0.15 - 0.27 nM
GABA	2.5 uM	42.55 - 68.38 uM	1.77 - 2.55 uM
SKF-97541**	not determined	11.09 - 11.47 uM	0.80 - 0.96 uM
(-)Baclofen	0.5 uM	31.46 - 53.70 uM	3.92 - 7.78 uM
(+)Baclofen	not determined	no fit	1.25 - 3.94 mM
Saclofen	156 uM	280.5 - 365.0 uM	119.4 - 131.4 uM
L-Glutamate	not determined	119.4 - 285.0 mM	116.2 - 201.6 mM

\* reported by Kaupmann et al., (1997) *Nature* **386**, 239-246

\*\* 3-aminopropyl(methyl)phosphinic acid

In Table 1, gb1a refers to GABA<sub>B</sub>R1a and gb1a/gb2 refers to HG20/GABA<sub>B</sub>R1a heterodimers.

10

Co-localization studies were performed to determine if mRNAs for GABA<sub>B</sub>R1a and HG20 co-exist in the same cells in the brain. Figure 10A-B shows equivalent levels of GABA<sub>B</sub>R1a and HG20 hybridization in adjacent coronal sections of rat parietal cortex, indicating that messages for both receptors are expressed in this brain region. Radiolabelled and fluorescent probes for the two receptors were used to look at the cellular level where it was observed that message for both receptors is expressed in the same cells (Example 13 and Figure 10C-E). In the parietal cortex and all other major brain regions studied, including the hippocampus, thalamus, cerebellum, and vestibular ganglion, GABA<sub>B</sub>R1a and HG20 mRNAs are co-localized in the same cells. These results suggest that the functional native GABA<sub>B</sub> receptors found in these cells involve both GABA<sub>B</sub>R1a and HG20. Co-immunoprecipitation, functional, and anatomical data described herein converge to strongly support the argument that the native, functional GABA<sub>B</sub> receptor is a heterodimer of GABA<sub>B</sub>R1a and HG20. This work is particularly exciting because it represents the first example of a heteromeric G protein-coupled receptor.

15

The novel murine GABA<sub>B</sub>R1a DNA sequences of the present, in whole or in part, can be linked with other DNA sequences, *i.e.*, DNA sequences to which GABA<sub>B</sub>R1a DNA is not naturally linked, to form “recombinant DNA molecules” encoding murine GABA<sub>B</sub>R1a. Such other sequences can include DNA

sequences that control transcription or translation such as, *e.g.*, translation initiation sequences, promoters for RNA polymerase II, transcription or translation termination sequences, enhancer sequences, sequences that control replication in microorganisms, or that confer antibiotic resistance. The novel DNA sequences of the present  
5 invention can be inserted into vectors such as plasmids, cosmids, viral vectors, or yeast artificial chromosomes.

The present invention also includes isolated forms of DNA encoding GABA<sub>B</sub>R1a. By “isolated DNA encoding GABA<sub>B</sub>R1a” is meant DNA encoding GABA<sub>B</sub>R1a that has been isolated from a natural source or produced by recombinant  
10 means. Use of the term “isolated” indicates that DNA encoding GABA<sub>B</sub>R1a is not present in its normal cellular environment. Thus, an isolated DNA encoding GABA<sub>B</sub>R1a may be in a cell-free solution or placed in a different cellular environment from that in which it occurs naturally. The term isolated does not imply that isolated DNA encoding GABA<sub>B</sub>R1a is the only DNA present, but instead means  
15 that isolated DNA encoding GABA<sub>B</sub>R1a is at least 95% free of non-nucleic acid material (*e.g.*, proteins, lipids, carbohydrates) naturally associated with the DNA encoding GABA<sub>B</sub>R1a. Thus, DNA encoding GABA<sub>B</sub>R1a that is expressed in bacteria or even in eukaryotic cells which do not naturally (*i.e.*, without human intervention) contain it through recombinant means is “isolated DNA encoding  
20 GABA<sub>B</sub>R1a.”

Another aspect of the present invention includes host cells that have been engineered to contain and/or express DNA sequences encoding murine GABA<sub>B</sub>R1a. Such recombinant host cells can be cultured under suitable conditions to produce murine GABA<sub>B</sub>R1a protein. An expression vector containing DNA  
25 encoding the murine GABA<sub>B</sub>R1a protein can be used for expression of the murine GABA<sub>B</sub>R1a protein in a recombinant host cell. Recombinant host cells may be prokaryotic or eukaryotic, including but not limited to, bacteria such as *E. coli*, fungal cells such as yeast, mammalian cells including, but not limited to, cell lines of human, bovine, porcine, monkey and rodent origin, and insect cells including but not limited  
30 to *Drosophila* and silkworm derived cell lines. Cell lines derived from mammalian species which are suitable for recombinant expression of the murine GABA<sub>B</sub>R1a protein and which are commercially available, include but are not limited to, L cells L-M(TK<sup>-</sup>) (ATCC CCL 1.3), L cells L-M (ATCC CCL 1.2), HEK293 (ATCC CRL 1573), Raji (ATCC CCL 86), CV-1 (ATCC CCL 70), COS-1 (ATCC CRL 1650),

COS-7 (ATCC CRL 1651), CHO-K1 (ATCC CCL 61), 3T3 (ATCC CCL 92), NIH/3T3 (ATCC CRL 1658), HeLa (ATCC CCL 2), C127I (ATCC CRL 1616), BSC-1 (ATCC CCL 26), MRC-5 (ATCC CCL 171), *Xenopus* melanophores, and *Xenopus* oocytes.

5 A variety of mammalian expression vectors can be used to express recombinant murine GABA<sub>B</sub>R1a in mammalian cells. Commercially available mammalian expression vectors which are suitable include, but are not limited to, pMC1neo (Stratagene), pSG5 (Stratagene), pcDNAI and pcDNAIamp, pcDNA3, pcDNA3.1, pCR3.1 (Invitrogen), EBO-pSV2-neo (ATCC 37593), pBPV-1(8-2) 10 (ATCC 37110), pdBPV-MMTneo(342-12) (ATCC 37224), pRSVgpt (ATCC 37199), pRSVneo (ATCC 37198), pSV2-dhfr (ATCC 37146), and the PT7TS oocyte expression vector (or similar expression vectors containing the globin 5' UTR and the globin 3' UTR). Following expression in recombinant cells, the murine GABA<sub>B</sub>R1a protein can be purified by conventional techniques to a level that is 15 substantially free from other proteins.

Other cells that are particularly suitable for expression of the murine GABA<sub>B</sub>R1a protein are immortalized melanophore pigment cells from *Xenopus laevis*. Such melanophore pigment cells can be used for functional assays using recombinant expression of murine GABA<sub>B</sub>R1a in a manner similar to the use of such 20 melanophore pigment cells for the functional assay of other recombinant GPCRs (Graminski et al., 1993, J. Biol. Chem. 268:5957-5964; Lerner, 1994, Trends Neurosci. 17:142-146; Potenza & Lerner, 1992, Pigment Cell Res. 5:372-378; Potenza et al., 1992, Anal. Biochem. 206:315-322).

25 The present invention includes a method of producing the murine GABA<sub>B</sub>R1a protein comprising:

- (a) transfecting a host cell with a expression vector comprising DNA that encodes the murine GABA<sub>B</sub>R1a protein;
- (b) growing the host cells under conditions such that the murine GABA<sub>B</sub>R1a protein is produced; and
- 30 (c) recovering the murine GABA<sub>B</sub>R1a protein from the host cells.

In particular embodiments, the method of recovering the murine GABA<sub>B</sub>R1a protein may involve obtaining membrane preparations from the host cells that contain the murine GABA<sub>B</sub>R1a protein. Such membrane preparations may

contain heterodimers of GABA<sub>B</sub>R1a protein and HG20 protein that form functional GABA<sub>B</sub> receptors.

In particular embodiments, the cells are eukaryotic cells. In other embodiments, the cells are mammalian cells. In still other embodiments, the cells are 5 COS cells, in particular COS-7 cells (ATCC CRL 1651), COS-1 cells (ATCC CRL 1650), HEK293 cells (ATCC CRL 1573), or *Xenopus* melanophores.

The present inventors have discovered that, when either HG20 or GABA<sub>B</sub>R1a subunits are recombinantly expressed separately, *i.e.*, in different cells, very little or no expression is observed. It is only when HG20 and GABA<sub>B</sub>R1a 10 subunits are recombinantly co-expressed, *i.e.*, expressed in the same cells at the same time, that high level expression of HG20 and GABA<sub>B</sub>R1a is observed (see Figure 25). Given the close relationship among GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20 (see Figure 24), and the close relationship that is 15 expected to be found between other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b, it is believed that co-expression of HG20 and either GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b will also result in increased expression of HG20 and GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b as compared to expression of these proteins 20 separately.

Accordingly, the present invention includes a method of co-expressing HG20 and GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b so as to result in an increase in expression of HG20 and GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes 25 related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b as compared to expression when HG20 and GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b are expressed separately. In particular embodiments, the level of expression of HG20, GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes related to 30 GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b is measured in the co-expressing cells. In particular embodiments, the level of expression of HG20, GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b is measured by immunoblot or by immunoprecipitation/immunoblotting methods.

Thus, the present invention includes a method of increasing expression of HG20 and GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b comprising:

- (a) recombinantly expressing HG20 and GABA<sub>B</sub>R1a,
- 5 GABA<sub>B</sub>R1b, *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b in the same cells;
- (b) measuring the expression of HG20, GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b, where a measurement of detectable expression of HG20,
- 10 GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b indicates that increased expression has been achieved.

In particular embodiments, the measurement of expression is carried out by immunoblotting with or without immunoprecipitation.

- 15 In other embodiments, the method also comprises the steps of recombinantly expressing HG20 and GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b separately, measuring the level of expression of HG20, GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b in the separately expressing cells, and comparing the amount of expression of HG20, GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b in the separately expressing cells to the amount of expression of HG20, GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b in the co-expressing cells.
- 20
- 25

Accordingly, the present invention includes a method of increasing expression of HG20 and GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b comprising:

- 30 (a) recombinantly expressing HG20 and GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b in the same cells to form co-expressing cells;

(b) recombinantly expressing HG20 and GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b in different cells to form separately expressing cells;

(c) measuring the expression of HG20, GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b,

5 5 *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b in the co-expressing cells;

(d) measuring the expression of HG20, GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b in the separately expressing cells;

10 10 where if the amount of expression of HG20, GABA<sub>B</sub>R1a, GABA<sub>B</sub>R1b, *C. elegans* genes related to GABA<sub>B</sub>R1a and HG20, or other isoforms of GABA<sub>B</sub>R1a and GABA<sub>B</sub>R1b is greater in the co-expressing cells as compared to the separately expressing cells, this indicates that increased expression has been achieved.

15 15 In particular embodiments, the measurement of expression is carried out by immunoblotting with or without immunoprecipitation.

The present invention includes murine GABA<sub>B</sub>R1a protein substantially free from other proteins. The amino acid sequence of the full-length murine GABA<sub>B</sub>R1a protein is shown in Figure 16 as SEQ.ID.NO.:20. Thus, the

20 20 present invention includes polypeptides comprising the murine GABA<sub>B</sub>R1a protein substantially free from other proteins having the amino acid sequence SEQ.ID.NO.:20. The present invention also includes murine GABA<sub>B</sub>R1a protein lacking a signal sequence as well as DNA encoding such a protein. Such a murine GABA<sub>B</sub>R1a protein lacking a signal sequence is represented by amino acids 18-960 of SEQ.ID.NO.:20.

The present invention includes modified murine GABA<sub>B</sub>R1a polypeptides which have amino acid deletions, additions, or substitutions but that still retain substantially the same biological activity as native murine GABA<sub>B</sub>R1a protein. The present invention includes polypeptides where one amino acid substitution has been made in SEQ.ID.NO.:20 or in a polypeptide represented by SEQ.ID.NO.:20 lacking a signal sequence, wherein the polypeptides still retain substantially the same biological activity as native murine GABA<sub>B</sub>R1a protein. The present invention also includes polypeptides where two or more amino acid substitutions have been made in SEQ.ID.NO.:20 or in a polypeptide represented by SEQ.ID.NO.:20 lacking a signal

sequence, wherein the polypeptides still retain substantially the same biological activity as native murine GABA<sub>B</sub>R1a protein. In particular, the present invention includes embodiments where the above-described substitutions are conservative substitutions. In particular, the present invention includes embodiments where the above-described substitutions do not occur in the ligand-binding domain of native murine GABA<sub>B</sub>R1a protein. In particular, the present invention includes embodiments where amino acid changes have been made in positions of native murine GABA<sub>B</sub>R1a protein where the amino acid sequence of native murine GABA<sub>B</sub>R1a protein differs from the amino acid sequence of HG20 when the amino acid sequences of native murine GABA<sub>B</sub>R1a protein and HG20 are aligned in a manner similar to the alignment of the amino acid sequences of GABA<sub>B</sub>R1b protein and HG20 shown in Figure 8.

The present invention also includes isolated forms of murine GABA<sub>B</sub>R1a proteins. By “isolated murine GABA<sub>B</sub>R1a protein” is meant murine GABA<sub>B</sub>R1a protein that has been isolated from a natural source or produced by recombinant means. Use of the term “isolated” indicates that murine GABA<sub>B</sub>R1a protein is not present in its normal cellular environment. Thus, an isolated murine GABA<sub>B</sub>R1a protein may be in a cell-free solution or placed in a different cellular environment from that in which it occurs naturally. The term isolated does not imply that an isolated murine GABA<sub>B</sub>R1a protein is the only protein present, but instead means that an isolated murine GABA<sub>B</sub>R1a protein is at least 95% free of non-amino acid material (e.g., nucleic acids, lipids, carbohydrates) naturally associated with the murine GABA<sub>B</sub>R1a protein. Thus, an murine GABA<sub>B</sub>R1a protein that is expressed in bacteria or even in eukaryotic cells which do not naturally (i.e., without human intervention) express it through recombinant means is an “isolated murine GABA<sub>B</sub>R1a protein.”

The present invention also provides ligand-binding domains of murine GABA<sub>B</sub>R1a protein. A FASTA search of the database GenBank (bacterial division) using the N-terminal domain of murine GABA<sub>B</sub>R1a (amino acid positions 147-551 of SEQ.ID.NO.:20) as the probe reveals a match with the *E.coli* leucine-specific binding protein (livK) (22% identity over 339 amino acids), whereas no match to any bacterial amino acid binding protein is found using the receptor sequence inclusive of the region that includes the seven transmembrane domains (TM 1-7; amino acid positions 552-960) as a probe. The ligand-binding domain(s) of GABA<sub>B</sub>R1a was

also experimentally determined. Photoaffinity [<sup>125</sup>I]CGP71872 labeling experiments provided direct physical evidence that the N-terminal extracellular domain but not a C-terminal fragment of GABA<sub>B</sub>R1a (comprising TM1-7 and inclusive to the carboxyl tail) is responsible for ligand-binding (see Examples 14-19 and Figure 17B).

5 Accordingly, the present invention includes a polypeptide comprising the ligand binding domain of murine GABA<sub>B</sub>R1a. In preferred embodiments, the polypeptide comprises amino acids 147-551 of SEQ.ID.NO.:20.

The present invention includes methods of identifying compounds that specifically bind to the GABA<sub>B</sub> receptor, as well as compounds identified by such 10 methods. The specificity of binding of compounds showing affinity for the GABA<sub>B</sub> receptor is shown by measuring the affinity of the compounds for recombinant cells expressing HG20 and either GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b, or for membranes from such cells. Expression of the GABA<sub>B</sub> receptor and screening for compounds that bind to the GABA<sub>B</sub> receptor or that inhibit the binding of a known, radiolabelled 15 ligand of the GABA<sub>B</sub> receptor, *e.g.*, an amino acid or a GABA analogue such as (-)baclofen, to these cells, or membranes prepared from these cells, provides an effective method for the rapid selection of compounds with high affinity for the GABA<sub>B</sub> receptor. Other radiolabelled ligands that might be used are ibotenic acid, the amino acids glutamate and glycine, other amino acids, decarboxylated amino 20 acids, or any of the other GABA<sub>B</sub> receptor ligands disclosed herein or known in the art. Such ligands need not necessarily be radiolabelled but can also be nonisotopic compounds that can be used to displace bound radiolabelled compounds or that can be used as activators in functional assays. Compounds identified by the methods disclosed herein are likely to be agonists or antagonists of the GABA<sub>B</sub> receptor and 25 may be peptides, proteins, or non-proteinaceous organic molecules.

Therefore, the present invention includes assays by which GABA<sub>B</sub> receptor agonists and antagonists can be identified. Methods for identifying agonists and antagonists of other receptors are well known in the art and can often be adapted to identify agonists and antagonists of the GABA<sub>B</sub> receptor. Accordingly, the present 30 invention includes a method for determining whether a substance binds GABA<sub>B</sub> receptors and is thus a potential agonist or antagonist of the GABA<sub>B</sub> receptor that comprises:

(a) providing cells comprising an expression vector encoding HG20 and an expression vector encoding GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b;

(b) culturing the cells under conditions such that HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b are expressed and heterodimers of HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b are formed;

(c) exposing the cells to a labeled ligand of GABA<sub>B</sub> receptors in the presence and in the absence of the substance;

(d) measuring the binding of the labeled ligand to the heterodimers of HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b in the presence and in the absence of the substance;

where if the amount of binding of the labeled ligand is less in the presence of the substance than in the absence of the substance, then the substance is a potential agonist or antagonist of GABA<sub>B</sub> receptors.

Examples of ligands of GABA<sub>B</sub> receptors are: CGP71872, GABA, saclofen, (-)baclofen, glycine, and (L)-glutamic acid.

The present invention also includes a method for determining whether a substance is capable of binding to GABA<sub>B</sub> receptors, *i.e.*, whether the substance is a potential agonist or an antagonist of GABA<sub>B</sub> receptors, where the method comprises:

(a) providing test cells comprising an expression vector encoding HG20 and an expression vector encoding GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b;

(b) culturing the test cells under conditions such that HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b are expressed and heterodimers of HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b are formed;

(c) exposing the test cells to the substance;

(d) measuring the amount of binding of the substance to the test cells;

(e) measuring the amount of binding of the substance to control cells;

(f) comparing the amount of binding of the substance to the test cells with the amount of binding of the substance to control cells;

where if the amount of binding of the substance to the test cells is greater than the amount of binding of the substance to control cells, then the substance is capable of binding to GABA<sub>B</sub> receptors;

where the control cells are essentially the same as the test cells except that the control cells do not comprise an expression vector encoding HG20 and an expression vector encoding GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b.

Once a substance has been identified by the above-described methods, determining whether the substance is an agonist or antagonist can then be accomplished by the use of functional assays such as those described herein.

5 In particular embodiments, the cells are transfected with an expression vector encoding HG20 and an expression vector encoding GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b.

In particular embodiments, the binding affinity of the substance for the test cells is determined. In particular embodiments, such binding affinity is between 1nM and 200 mM; preferably between 5 nM and 1 mM; more preferably between 10 10 nM and 100  $\mu$ M; and even more preferably between 10 nM and 100 nM.

15 The conditions under which step (c) of the above-described methods is practiced are conditions that are typically used in the art for the study of protein-ligand interactions: *e.g.*, physiological pH; salt conditions such as those represented by such commonly used buffers as PBS or in tissue culture media; a temperature of about 4°C to about 55°C.

20 In a particular embodiment of the above-described methods, the cells are eukaryotic cells. In another embodiment, the cells are mammalian cells. In other embodiments, the cells are L cells L-M(TK<sup>-</sup>) (ATCC CCL 1.3), L cells L-M (ATCC CCL 1.2), HEK293 (ATCC CRL 1573), Raji (ATCC CCL 86), CV-1 (ATCC CCL 70), COS-1 (ATCC CRL 1650), COS-7 (ATCC CRL 1651), CHO-K1 (ATCC CCL 61), 3T3 (ATCC CCL 92), NIH/3T3 (ATCC CRL 1658), HeLa (ATCC CCL 2), C127I (ATCC CRL 1616), BS-C-1 (ATCC CCL 26), MRC-5 (ATCC CCL 171), or *Xenopus* melanophores.

25 The assays described above can be carried out with cells that have been transiently or stably transfected with an expression vector encoding HG20 and an expression vector encoding GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b. Transfection is meant to include any method known in the art for introducing HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b into the test cells. For example, transfection includes calcium phosphate or calcium chloride mediated transfection, lipofection, infection with a retroviral 30 construct, and electroporation. In particular embodiments, a single expression vector encodes HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b.

Where binding of the substance or ligand is measured, such binding can be measured by employing a labeled substance or ligand. The substance or ligand

can be labeled in any convenient manner known to the art, *e.g.*, radioactively, fluorescently, enzymatically.

In particular embodiments of the above-described methods, the substance or ligand is an amino acid or an amino acid analogue such as CGP71872, 5 GABA, saclofen, (-)baclofen, glycine, and (L)-glutamic acid.

In particular embodiments of the above-described methods, HG20 has an amino acid sequence of SEQ.ID.NO.:2.

In particular embodiments of the above-described methods, HG20 comprises an amino acid sequence selected from the group consisting of:

10 SEQ.ID.NO.:2;  
Positions 9-941 of SEQ.ID.NO.:2;  
Positions 35-941 of SEQ.ID.NO.:2;  
Positions 36-941 of SEQ.ID.NO.:2;  
Positions 38-941 of SEQ.ID.NO.:2;  
15 Positions 39-941 of SEQ.ID.NO.:2;  
Positions 42-941 of SEQ.ID.NO.:2;  
Positions 44-941 of SEQ.ID.NO.:2;  
Positions 46-941 of SEQ.ID.NO.:2;  
Positions 52-941 of SEQ.ID.NO.:2; and  
20 Positions 57-941 of SEQ.ID.NO.:2.

In particular embodiments, GABA<sub>BR</sub>1a is murine GABA<sub>BR</sub>1a and has the amino acid sequence SEQ.ID.NO.:20. In particular embodiments, GABA<sub>BR</sub>1a is rat GABA<sub>BR</sub>1a and has the amino acid sequence reported in Kaupmann et al., 1997, Nature 386:239-246. In particular embodiments, 25 GABA<sub>BR</sub>1b is rat GABA<sub>BR</sub>1b and has the amino acid sequence reported in Kaupmann et al., 1997, Nature 386:239-246. In particular embodiments, GABA<sub>BR</sub>1a is human GABA<sub>BR</sub>1a and has an amino acid sequence selected from the group consisting of: SEQ.ID.NO.:21 and the protein encoded by SEQ.ID.NO.:23.

The above-described methods can be modified in that, rather than 30 exposing cells to the substance, membranes can be prepared from the cells and those membranes can be exposed to the substance. Such a modification utilizing membranes rather than cells is well known in the art with respect to other receptors and is described in, *e.g.*, Hess et al., 1992, Biochem. Biophys. Res. Comm. 184:260-268.

As a further modification of the above-described method, RNA encoding HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b can be prepared as, e.g., by *in vitro* transcription using a plasmid containing HG20 and a plasmid containing GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b under the control of a bacteriophage T7 promoter, and the RNA can

5 be microinjected into *Xenopus* oocytes in order to cause the expression of HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b in the oocytes. Substances are then tested for binding to the heterodimer of HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b expressed in the oocytes. Alternatively, rather than detecting binding, the effect of the substances on the electrophysiological properties of the oocytes can be determined.

10 The present invention includes assays by which GABA<sub>B</sub> receptor agonists and antagonists may be identified by their ability to stimulate or antagonize a functional response mediated by the GABA<sub>B</sub> receptor in cells that have been co-transfected with and that co-express HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b.

15 Accordingly, the present invention provides a method of identifying agonists and antagonists of HG20 comprising:

- (a) providing test cells by transfecting cells with:
  - (1) an expression vector that directs the expression of HG20 in the cells; and
  - (2) an expression vector that directs the expression of GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b in the cells;
- (b) exposing the test cells to a substance that is suspected of being an agonist of the GABA<sub>B</sub> receptor;
- (c) measuring the amount of a functional response of the test cells that have been exposed to the substance;
- 20 (d) comparing the amount of the functional response exhibited by the test cells with the amount of the functional response exhibited by control cells; wherein if the amount of the functional response exhibited by the test cells differs from the amount of the functional response exhibited by the control cells, the substance is an agonist or antagonist of the GABA<sub>B</sub> receptor;
- 25 (e) where the control cells are cells that have not been transfected with HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b but have been exposed to the substance or are test cells that have not been exposed to the substance.

In particular embodiments of the above-described methods, HG20 has an amino acid sequence of SEQ.ID.NO.:2.

In particular embodiments of the above-described methods, HG20 comprises an amino acid sequence selected from the group consisting of:

SEQ.ID.NO.:2;  
5 Positions 9-941 of SEQ.ID.NO.:2;  
Positions 35-941 of SEQ.ID.NO.:2;  
Positions 36-941 of SEQ.ID.NO.:2;  
Positions 38-941 of SEQ.ID.NO.:2;  
Positions 39-941 of SEQ.ID.NO.:2;  
Positions 42-941 of SEQ.ID.NO.:2;  
10 Positions 44-941 of SEQ.ID.NO.:2;  
Positions 46-941 of SEQ.ID.NO.:2;  
Positions 52-941 of SEQ.ID.NO.:2; and  
Positions 57-941 of SEQ.ID.NO.:2.  
15 In particular embodiments, GABA<sub>B</sub>R1a is murine GABA<sub>B</sub>R1a and has the amino acid sequence SEQ.ID.NO.:20. In particular embodiments, GABA<sub>B</sub>R1a is rat GABA<sub>B</sub>R1a and has the amino acid sequence reported in Kaupmann et al., 1997, *Nature* 386:239-246. In particular embodiments, GABA<sub>B</sub>R1b is rat GABA<sub>B</sub>R1b and has the amino acid sequence reported in Kaupmann et al., 1997, *Nature* 386:239-246. In particular embodiments, GABA<sub>B</sub>R1a is human GABA<sub>B</sub>R1a and has an amino acid sequence selected from the group 20 consisting of: SEQ.ID.NO.:21 and the protein encoded by SEQ.ID.NO.:23.

In particular embodiments, the functional response is selected from the group consisting of: changes in pigment distribution in melanophore cells; changes in cAMP or calcium concentration; and changes in membrane currents in *Xenopus* oocytes. In particular embodiments, the change in pigment distribution is pigment aggregation; the change in cAMP concentration is a decrease in cAMP concentration; the change in membrane current is the modulation of an inwardly rectifying potassium current.

In a particular embodiment of the above-described method, the cells 30 are eukaryotic cells. In another embodiment, the cells are mammalian cells. In other embodiments, the cells are L cells L-M(TK<sup>-</sup>) (ATCC CCL 1.3), L cells L-M (ATCC CCL 1.2), 293 (ATCC CRL 1573), Raji (ATCC CCL 86), CV-1 (ATCC CCL 70), COS-1 (ATCC CRL 1650), COS-7 (ATCC CRL 1651), CHO-K1 (ATCC CCL 61), 3T3 (ATCC CCL 92), NIH/3T3 (ATCC CRL 1658), HeLa (ATCC CCL 2), C127I

(ATCC CRL 1616), BS-C-1 (ATCC CCL 26), MRC-5 (ATCC CCL 171), *Xenopus* melanophores, or *Xenopus* oocytes.

In a particular embodiment of the above-described method, the cells are transfected with separate expression vectors that direct the expression of HG20 and either GABA<sub>A</sub>R1a or GABA<sub>A</sub>R1b in the cells. In other embodiments, the cells are transfected with a single expression vector that direct the expression of both HG20 and GABA<sub>A</sub>R1a or GABA<sub>A</sub>R1b in the cells.

In a particular embodiment, the cells are *Xenopus* melanophores and the functional response is pigment aggregation. In another embodiment, the cells are HEK293 cells and the functional response is a decrease in cAMP level. In another embodiment, the cells are *Xenopus* oocytes and the functional response is the production of an inwardly rectifying potassium current.

The conditions under which step (b) of the method is practiced are conditions that are typically used in the art for the study of protein-ligand interactions: e.g., physiological pH; salt conditions such as those represented by such commonly used buffers as PBS or in tissue culture media; a temperature of about 4°C to about 55°C.

The above-described assay can be easily modified to form a method to identify antagonists of the GABA<sub>B</sub> receptor. Such a method comprises:

- 20 (a) providing cells by transfecting cells with:
  - (1) an expression vector that directs the expression of HG20 in the cells; and
  - (2) an expression vector that directs the expression of GABA<sub>A</sub>R1a or GABA<sub>A</sub>R1b in the cells;
- 25 (b) exposing the cells to a substance that is a known agonist of the GABA<sub>B</sub> receptor;
- (c) measuring the amount of a functional response of the cells that have been exposed to the known agonist;
- (d) exposing the cells concurrently to the known agonist and to a substance that is suspected of being an antagonist of the GABA<sub>B</sub> receptor;
- 30 (e) measuring the amount of a functional response of the cells that have been exposed to the substance and the known agonist;
- (f) comparing the amount of the functional response measured in step (c) with the amount of the functional response measured in step (e);

wherein if the amount of the functional response measured in step (c) is greater than the amount of the functional response measured in step (e), the substance is an antagonist of the GABA<sub>B</sub> receptor.

Additional types of functional assays that can be used to identify 5 agonists and antagonists of GABA<sub>B</sub> receptors include transcription-based assays. Transcription-based assays involve the use of a reporter gene whose transcription is driven by an inducible promoter whose activity is regulated by a particular intracellular event such as, *e.g.*, changes in intracellular calcium levels that are caused by the interaction of a receptor with a ligand. Transcription-based assays are 10 reviewed in Rutter et al., 1998, Chemistry & Biology 5:R285-R290.

The transcription-based assays of the present invention rely on the expression of reporter genes whose transcription is activated or repressed as a result of intracellular events that are caused by the interaction of an agonist with a heterodimer of HG20 and either GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b where the heterodimer 15 forms a functional GABA<sub>B</sub> receptor.

An extremely sensitive transcription based assay is disclosed in Zlokarnik et al., 1998, Science 279:84-88 (Zlokarnik) and also in U.S. Patent No. 5,741,657. The assay disclosed in Zlokarnik and U.S. Patent No. 5,741,657 employs 20 a plasmid encoding  $\beta$ -lactamase under the control of an inducible promoter. This plasmid is transfected into cells together with a plasmid encoding a receptor for which it is desired to identify agonists. The inducible promoter on the  $\beta$ -lactamase is chosen so that it responds to at least one intracellular signal that is generated when an agonist binds to the receptor. Thus, following such binding of agonist to receptor, the level of 25  $\beta$ -lactamase in the transfected cells increases. This increase in  $\beta$ -lactamase is made measurable by treating the cells with a cell-permeable dye that is a substrate for  $\beta$ -lactamase. The dye contains two fluorescent moieties. In the intact dye, the two 30 fluorescent moieties are close enough to one another that fluorescent resonance energy transfer (FRET) can take place between them. Following cleavage of the dye into two parts by  $\beta$ -lactamase, the two fluorescent moieties are located on different parts, and thus can drift apart. This increases the distance between the fluorescent moieties, thus decreasing the amount of FRET that can occur between them. It is this 35 decrease in FRET that is measured in the assay.

One skilled in the art can modify the assay described in Zlokarnik and U.S. Patent No. 5,741,657 to form an assay for identifying agonists of GABA<sub>B</sub>

receptors by using an inducible promoter to drive  $\beta$ -lactamase that is activated by an intracellular signal generated by the interaction of agonists and the GABA<sub>B</sub> receptor. To produce the GABA<sub>B</sub> receptor, a plasmid encoding HG20 and a plasmid encoding GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b would be transfected into the cells. The cells would be 5 exposed to the cell-permeable dye and then exposed to substances suspected of being agonists of the GABA<sub>B</sub> receptor. Those substances that cause a decrease in FRET are likely to actually be agonists of the GABA<sub>B</sub> receptor.

Accordingly, the present invention includes a method for identifying agonists of the GABA<sub>B</sub> receptor comprising:

- 10 (a) transfected cells with:
  - (1) an expression vector that directs the expression of HG20 in the cells;
  - (2) an expression vector that directs the expression of GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b in the cells;
  - (3) an expression vector that directs the expression of  $\beta$ -lactamase under the control of an inducible promoter that is activated by an intracellular signal generated by the interaction of agonists and the GABA<sub>B</sub> receptor;
- 15 (b) exposing the cells to a substrate of  $\beta$ -lactamase that is a cell-permeable dye that contains two fluorescent moieties where the two fluorescent
- 20 moieties are on different parts of the dye and cleavage of the dye by  $\beta$ -lactamase allows the two fluorescent moieties to drift apart;
- (c) measuring the amount of fluorescent resonance energy transfer (FRET) in the cells in the absence of the substance of step (d);
- 25 (d) exposing the cells to a substance that is suspected of being an agonist of the GABA<sub>B</sub> receptor;
- (e) measuring the amount of FRET in the cells after exposure of the cells to the substance;

wherein if the amount of FRET in the cells measured in step (e) is less than the amount of FRET measured in the cells in step (c), then the substance is an 30 agonist of the GABA<sub>B</sub> receptor.

Substeps (1)-(3) of step (a) can be practiced in any order.

The assay described above can be modified to an assay for identifying antagonists of the GABA<sub>B</sub> receptor. Such modification would involve the use of  $\beta$ -lactamase under the control of a promoter that is repressed by at least one intracellular

signal generated by interaction of an agonist with the GABA<sub>B</sub> receptor and would also involve running the assay in the presence of a known agonist. When the cells are exposed to substances suspected of being antagonists of the GABA<sub>B</sub> receptor,  $\beta$ -lactamase will be induced, and FRET will decrease, only if the substance tested is able to counteract the effect of the agonist, *i.e.*, only if the substance tested is actually an antagonist.

5 Accordingly, the present invention includes a method for identifying antagonists of the GABA<sub>B</sub> receptor comprising:

- (a) transfecting cells with:
  - 10 (1) an expression vector that directs the expression of HG20 in the cells;
  - (2) an expression vector that directs the expression of GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b in the cells;
  - (3) an expression vector that directs the expression of  $\beta$ -lactamase under the control of an inducible promoter that is repressed by at least one intracellular signal generated by interaction of an agonist with the GABA<sub>B</sub> receptor;
  - (b) exposing the cells to a known agonist of the GABA<sub>B</sub> receptor;
  - (c) exposing the cells to a substrate of  $\beta$ -lactamase that is a cell-permeable dye that contains two fluorescent moieties where the two fluorescent
- 15 (d) measuring the amount of fluorescent resonance energy transfer (FRET) in the cells in the absence of the substance of step (e);
- (e) exposing the cells to a substance that is suspected of being an antagonist of the GABA<sub>B</sub> receptor;
- 20 (f) measuring the amount of FRET in the cells after exposure of the cells to the substance;

25 wherein if the amount of FRET in the cells measured in step (f) is less than the amount of FRET measured in the cells in step (d), then the substance is an antagonist of the GABA<sub>B</sub> receptor.

Substeps (1)-(3) of step (a) can be practiced in any order.

In particular embodiments of the assays employing  $\beta$ -lactamase described above, the cells are eukaryotic cells. In particular embodiments, the cells are mammalian cells. In particular embodiments, the cells are selected from the group

consisting of: L cells L-M(TK<sup>-</sup>) (ATCC CCL 1.3), L cells L-M (ATCC CCL 1.2), 293 (ATCC CRL 1573), Raji (ATCC CCL 86), CV-1 (ATCC CCL 70), COS-1 (ATCC CRL 1650), COS-7 (ATCC CRL 1651), CHO-K1 (ATCC CCL 61), 3T3 (ATCC CCL 92), NIH/3T3 (ATCC CRL 1658), HeLa (ATCC CCL 2), C127I (ATCC CRL 1616), BS-C-1 (ATCC CCL 26), MRC-5 (ATCC CCL 171), *Xenopus* melanophores, and *Xenopus* oocytes.

5 In other embodiments, the inducible promoter that is repressed by at least one intracellular signal generated by interaction of an agonist with the GABA<sub>B</sub> receptor is a promoter that is repressed by decreases in cAMP levels or changes in 10 potassium currents.

In other embodiments, the inducible promoter that is activated by at least one intracellular signal generated by interaction of an agonist with the GABA<sub>B</sub> receptor is a promoter that is activated by decreases in cAMP levels or changes in potassium currents.

15 In other embodiments, the known agonist is selected from the group consisting of: GABA, saclofen, (-)baclofen, glycine, and (L)-glutamic acid.

In other embodiments,  $\beta$ -lactamase is TEM-1  $\beta$ -lactamase from *Escherichia coli*.

20 In other embodiments, the substrate of  $\beta$ -lactamase is CCF2/AM (Zlokarnik et al., 1998, Science 279:84-88).

In other embodiments, HG20 has an amino acid sequence of SEQ.ID.NO.:2.

In other embodiments of the above-described methods, HG20 comprises an amino acid sequence selected from the group consisting of:

25 SEQ.ID.NO.:2;

Positions 9-941 of SEQ.ID.NO.:2;

Positions 35-941 of SEQ.ID.NO.:2;

Positions 36-941 of SEQ.ID.NO.:2;

Positions 38-941 of SEQ.ID.NO.:2;

30 Positions 39-941 of SEQ.ID.NO.:2;

Positions 42-941 of SEQ.ID.NO.:2;

Positions 44-941 of SEQ.ID.NO.:2;

Positions 46-941 of SEQ.ID.NO.:2;

Positions 52-941 of SEQ.ID.NO.:2; and

Positions 57-941 of SEQ.ID.NO.:2.

In other embodiments, GABA<sub>B</sub>R1a is murine GABA<sub>B</sub>R1a and has the amino acid sequence SEQ.ID.NO.:20. In other embodiments, GABA<sub>B</sub>R1a is rat GABA<sub>B</sub>R1a and has the amino acid sequence reported in Kaupmann et al., 1997, Nature 386:239-246. In other embodiments, GABA<sub>B</sub>R1b is rat GABA<sub>B</sub>R1b and has the amino acid sequence reported in Kaupmann et al., 1997, Nature 386:239-246. In other embodiments, GABA<sub>B</sub>R1a is human GABA<sub>B</sub>R1a and has an amino acid sequence selected from the group consisting of: SEQ.ID.NO.:21 and the protein encoded by SEQ.ID.NO.:23.

10 In particular embodiments, the cells express a promiscuous G-protein, *e.g.*, G $\alpha$ 15 or G $\alpha$ 16.

15 In particular embodiments, the inducible promoter is a promoter that is activated or repressed by NF- $\kappa$ B or NFAT.

20 The assays described above could be modified to identify inverse agonists. In such assays, one would expect a decrease in  $\beta$ -lactamase activity. Similarly, inverse agonists can be identified by modifying the functional assays that were described previously where those functional assays monitored decreases in cAMP levels. In the case of assays for inverse agonists, increases in cAMP levels would be observed.

25 Other transcription-based assays that can be used to identify agonists and antagonists of the GABA<sub>B</sub> receptor rely on the use of green fluorescent proteins or luciferase as reporter genes. An example of such an assay comprises:

(a) transfecting cells with:

(1) an expression vector that directs the expression of HG20 in the cells;

(2) an expression vector that directs the expression of GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b in the cells;

(3) an expression vector that directs the expression of green fluorescent protein (GFP) under the control of an inducible promoter that is activated by an intracellular signal generated by the interaction of agonists and the GABA<sub>B</sub> receptor;

30 (b) measuring the amount of fluorescence from GFP in the cells;

(c) exposing the cells to a substance that is suspected of being an agonist of the GABA<sub>B</sub> receptor;

(d) measuring the amount of fluorescence from GFP in the cells that have been exposed to the substance;

wherein if the amount of fluorescence from GFP in the cells measured in step (b) is less than the amount of fluorescence from GFP measured in the cells in step (d), then the substance is an agonist of the GABA<sub>B</sub> receptor.

5 The present invention also includes assays for the identification of agonists or antagonists of GABA<sub>B</sub> receptors that are based upon FRET between a first and a second fluorescent dye where the first dye is bound to one side of the plasma membrane of a cell expressing a heterodimer of HG20 and GABA<sub>B</sub>R1a or

10 GABA<sub>B</sub>R1b and the second dye is free to shuttle from one face of the membrane to the other face in response to changes in membrane potential. In certain embodiments, the first dye is impenetrable to the plasma membrane of the cells and is bound predominately to the extracellular surface of the plasma membrane. The second dye is trapped within the plasma membrane but is free to diffuse within the membrane.

15 At normal (*i.e.*, negative) resting potentials of the membrane, the second dye is bound predominately to the inner surface of the extracellular face of the plasma membrane, thus placing the second dye in close proximity to the first dye. This close proximity allows for the generation of a large amount of FRET between the two dyes.

Following membrane depolarization, the second dye moves from the extracellular

20 face of the membrane to the intracellular face, thus increasing the distance between the dyes. This increased distance results in a decrease in FRET, with a corresponding increase in fluorescent emission derived from the first dye and a corresponding decrease in the fluorescent emission from the second dye. See figure 1 of González & Tsien, 1997, Chemistry & Biology 4:269-277. See also González & Tsien, 1995, Biophys. J. 69:1272-1280 and U.S. Patent No. 5,661,035.

25

In certain embodiments, the first dye is a fluorescent lectin or a fluorescent phospholipid that acts as the fluorescent donor. Examples of such a first dye are: a coumarin-labeled phosphatidylethanolamine (*e.g.*, N-(6-chloro-7-hydroxy-2-oxo-2H-1-benzopyran-3-carboxamidoacetyl)-dimyristoylphosphatidyl-30 ethanolamine) or N-(7-nitrobenz-2-oxa-1,3-diazol-4-yl)-dipalmitoylphosphatidylethanolamine); a fluorescently-labeled lectin (*e.g.*, fluorescein-labeled wheat germ agglutinin). In certain embodiments, the second dye is an oxonol that acts as the fluorescent acceptor. Examples of such a second dye are: bis(1,3-dialkyl-2-thiobarbiturate)trimethineoxonols (*e.g.*, bis(1,3-dihexyl-2-

thiobarbiturate)trimethineoxonol) or pentamethineoxonol analogues (*e.g.*, bis(1,3-dihexyl-2-thiobarbiturate)pentamethineoxonol; or bis(1,3-dibutyl-2-thiobarbiturate)pentamethineoxonol). See González & Tsien, 1997, Chemistry & Biology 4:269-277 for methods of synthesizing various dyes suitable for use in the present invention. In certain embodiments, the assay may comprise a natural carotenoid, *e.g.*, astaxanthin, in order to reduce photodynamic damage due to singlet oxygen.

Accordingly, the present invention provides a method of identifying agonists of GABA<sub>B</sub> receptors comprising:

- 10 (a) providing test cells comprising:
  - (1) an expression vector that directs the expression of HG20 in the cells;
  - (2) an expression vector that directs the expression of GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b in the cells;
  - (3) an expression vector that directs the expression of an inwardly rectifying potassium channel;
  - (4) a first fluorescent dye, where the first dye is bound to one side of the plasma membrane; and
  - (5) a second fluorescent dye, where the second fluorescent dye is free to shuttle from one face of the plasma membrane to the other face in response to changes in membrane potential;
- 15 (b) exposing the test cells to a substance that is suspected of being an agonist of the GABA<sub>B</sub> receptor;
- 20 (c) measuring the amount of fluorescence resonance energy transfer (FRET) in the test cells that have been exposed to the substance;
- 25 (d) comparing the amount of FRET exhibited by the test cells that have been exposed to the substance with the amount of FRET exhibited by control cells;
- 30 wherein if the amount of FRET exhibited by the test cells is less than the amount of FRET exhibited by the control cells, the substance is an agonist of the GABA<sub>B</sub> receptor;
- 35 where the control cells are either (1) cells that are essentially the same as the test cells except that they do not comprise at least one of the items listed at (a)

(1)-(5) but have been exposed to the substance; or (2) test cells that have not been exposed to the substance.

The above-described assay can be easily modified to form a method to identify antagonists of the GABA<sub>B</sub> receptor. Such a method comprises:

5 (a) providing test cells comprising:  
(1) an expression vector that directs the expression of HG20 in the cells;  
(2) an expression vector that directs the expression of GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b in the cells;  
10 (3) an expression vector that directs the expression of an inwardly rectifying potassium channel;  
(4) a first fluorescent dye, where the first dye is bound to one side of the plasma membrane; and  
(5) a second fluorescent dye, where the second fluorescent dye is free to shuttle from one face of the plasma membrane to the other face in response to changes in membrane potential;

15 (b) exposing the test cells to a known agonist of the GABA<sub>B</sub> receptor in the presence of a substance that is suspected of being an antagonist of the GABA<sub>B</sub> receptor;

20 (c) exposing the test cells to the known agonist of the GABA<sub>B</sub> receptor in the absence of the substance that is suspected of being an antagonist of the GABA<sub>B</sub> receptor;

25 (d) measuring the amount of fluorescence resonance energy transfer (FRET) in the test cells of steps (b) and (c);  
(e) comparing the amount of FRET exhibited by the test cells of steps (b) and (c);  
30 where if the amount of FRET exhibited by the test cells of step (b) is greater than the amount of FRET exhibited by the test cells of step (c), the substance is an antagonist of the GABA<sub>B</sub> receptor.

In particular embodiments of the above-described methods, the expression vectors are transfected into the test cells.

In particular embodiments of the above-described methods, HG20 has an amino acid sequence of SEQ.ID.NO.:2.

In particular embodiments of the above-described methods, HG20 comprises an amino acid sequence selected from the group consisting of:

SEQ.ID.NO.:2;  
5 Positions 9-941 of SEQ.ID.NO.:2;  
Positions 35-941 of SEQ.ID.NO.:2;  
Positions 36-941 of SEQ.ID.NO.:2;  
Positions 38-941 of SEQ.ID.NO.:2;  
Positions 39-941 of SEQ.ID.NO.:2;  
Positions 42-941 of SEQ.ID.NO.:2;  
10 Positions 44-941 of SEQ.ID.NO.:2;  
Positions 46-941 of SEQ.ID.NO.:2;  
Positions 52-941 of SEQ.ID.NO.:2; and  
Positions 57-941 of SEQ.ID.NO.:2.

In particular embodiments of the above-described methods,

15 GABA<sub>B</sub>R1a is murine GABA<sub>B</sub>R1a and has the amino acid sequence SEQ.ID.NO.:20. In particular embodiments, GABA<sub>B</sub>R1a is rat GABA<sub>B</sub>R1a and has the amino acid sequence reported in Kaupmann et al., 1997, *Nature* 386:239-246. In particular embodiments, GABA<sub>B</sub>R1b is rat GABA<sub>B</sub>R1b and has the amino acid sequence reported in Kaupmann et al., 1997, *Nature* 386:239-246. In particular  
20 embodiments, GABA<sub>B</sub>R1a is human GABA<sub>B</sub>R1a and has an amino acid sequence selected from the group consisting of: SEQ.ID.NO.:21 and the protein encoded by SEQ.ID.NO.:23.

Inwardly rectifying potassium channels that are suitable for use in the methods of the present invention are disclosed in, *e.g.*, Misgeld et al., 1995, *Prog. Neurobiol.* 46:423-462; North, 1989, *Br. J. Pharmacol.* 98:13-23; Gahwiler et al., 1985, *Proc. Natl. Acad. Sci USA* 82:1558-1562; Andrade et al., 1986, *Science* 234:1261.

In particular embodiments of the above-described methods, the first fluorescent dye is selected from the group consisting of: a fluorescent lectin; a  
30 fluorescent phospholipid; a coumarin-labeled phosphatidylethanolamine; N-(6-chloro-7-hydroxy-2-oxo-2H-1-benzopyran-3-carboxamidoacetyl)-dimyristoylphosphatidylethanolamine; N-(7-nitrobenz-2-oxa-1,3-diazol-4-yl)-dipalmitoylphosphatidylethanolamine); and fluorescein-labeled wheat germ agglutinin.

In particular embodiments of the above-described methods, the second fluorescent dye is selected from the group consisting of: an oxonol that acts as the fluorescent acceptor; bis(1,3-dialkyl-2-thiobarbiturate)trimethineoxonols; bis(1,3-dihexyl-2-thiobarbiturate)trimethineoxonol; bis(1,3-dialkyl-2-thiobarbiturate)quatramethineoxonols; bis(1,3-dialkyl-2-thiobarbiturate)pentamethineoxonols; bis(1,3-dihexyl-2-thiobarbiturate)pentamethineoxonol; bis(1,3-dibutyl-2-thiobarbiturate)pentamethineoxonol; and bis(1,3-dialkyl-2-thiobarbiturate)hexamethineoxonols.

5 In a particular embodiment of the above-described methods, the cells are eukaryotic cells. In another embodiment, the cells are mammalian cells. In other embodiments, the cells are L cells L-M(TK<sup>-</sup>) (ATCC CCL 1.3), L cells L-M (ATCC CCL 1.2), 293 (ATCC CRL 1573), Raji (ATCC CCL 86), CV-1 (ATCC CCL 70), COS-1 (ATCC CRL 1650), COS-7 (ATCC CRL 1651), CHO-K1 (ATCC CCL 61), 10 3T3 (ATCC CCL 92), NIH/3T3 (ATCC CRL 1658), HeLa (ATCC CCL 2), C127I (ATCC CRL 1616), BS-C-1 (ATCC CCL 26), MRC-5 (ATCC CCL 171), *Xenopus* melanophores, or *Xenopus* oocytes.

15 In a particular embodiment of the above-described methods, the cells are transfected with separate expression vectors that direct the expression of HG20 and either GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b in the cells. In other embodiments, the cells are transfected with a single expression vector that direct the expression of both HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b in the cells.

20 The conditions under which step (b) of the first method described above and steps (b) and (c) of the second method described above are practiced are 25 conditions that are typically used in the art for the study of protein-ligand interactions: e.g., physiological pH; salt conditions such as those represented by such commonly used buffers as PBS or in tissue culture media; a temperature of about 4°C to about 55°C.

25 The GABA<sub>B</sub> receptor belongs to the class of proteins known as G- 30 protein coupled receptors (GPCRs). GPCRs transmit signals across cell membranes upon the binding of ligand. The ligand-bound GPCR interacts with a heterotrimeric G-protein, causing the G $\alpha$  subunit of the G-protein to disassociate from the G $\beta$  and G $\gamma$  subunits. The G $\alpha$  subunit can then go on to activate a variety of second messenger systems.

Generally, a particular GPCR is only coupled to a particular type of G-protein. Thus, to observe a functional response from the GPCR, it is necessary to ensure that the proper G-protein is present in the system containing the GPCR. It has been found, however, that there are certain G-proteins that are "promiscuous." These 5 promiscuous G-proteins will couple to, and thus transduce a functional signal from, virtually any GPCR. See Offermanns & Simon, 1995, J. Biol. Chem. 270:15175, 15180 (Offermanns). Offermanns described a system in which cells are transfected with expression vectors that result in the expression of one of a large number of GPCRs as well as the expression of one of the promiscuous G-proteins G $\alpha$ 15 or 10 G $\alpha$ 16. Upon the addition of an agonist of the GPCR to the transfected cells, the GPCR was activated and was able, via G $\alpha$ 15 or G $\alpha$ 16, to activate the  $\beta$  isoform of phospholipase C, leading to an increase in inositol phosphate levels in the cells.

Therefore, by making use of these promiscuous G-proteins as in Offermanns, it is possible to set up functional assays for the GABA $\beta$  receptor, even 15 in the absence of knowledge of the G-protein with which the GABA $\beta$  receptors coupled *in vivo*. One possibility for utilizing promiscuous G-proteins in connection with the GABA $\beta$  receptor includes a method of identifying agonists of the GABA $\beta$  receptor comprising:

(a) providing cells that express HG20, GABA $\beta$ R1a or 20 GABA $\beta$ R1b, and a promiscuous G-protein, where HG20 and either GABA $\beta$ R1a or GABA $\beta$ R1b form a heterodimer representing a functional GABA $\beta$  receptor;

(b) exposing the cells to a substance that is a suspected agonist of the GABA $\beta$  receptor;

(c) measuring the level of inositol phosphates in the cells; 25 where an increase in the level of inositol phosphates in the cells as compared to the level of inositol phosphates in the cells in the absence of the suspected agonist indicates that the substance is an agonist of the GABA $\beta$  receptor.

Levels of inositol phosphates can be measured by monitoring calcium mobilization. Intracellular calcium mobilization is typically assayed in whole cells 30 under a microscope using fluorescent dyes or in cell suspensions via luminescence using the aequorin assay.

In methods related to those described above, rather than using changes in inositol phosphate levels as an indication of GABA $\beta$  receptor function, potassium currents are measured. This is feasible since the GABA $\beta$  receptor, like other metabotropic

receptors, is expected to be coupled to potassium channels. Thus, one could measure  $\text{GABA}_\text{B}$  receptor coupling to GIRK2 channels or to other potassium channels in oocytes.

5 In a particular embodiment of the above-described method, the cells are eukaryotic cells. In another embodiment, the cells are mammalian cells. In other embodiments, the cells are L cells L-M(TK<sup>-</sup>) (ATCC CCL 1.3), L cells L-M (ATCC CCL 1.2), 293 (ATCC CRL 1573), Raji (ATCC CCL 86), CV-1 (ATCC CCL 70), COS-1 (ATCC CRL 1650), COS-7 (ATCC CRL 1651), CHO-K1 (ATCC CCL 61), 3T3 (ATCC CCL 92), NIH/3T3 (ATCC CRL 1658), HeLa (ATCC CCL 2), C127I 10 (ATCC CRL 1616), BS-C-1 (ATCC CCL 26), MRC-5 (ATCC CCL 171), or Xenopus oocytes.

In a particular embodiment of the above-described method, the cells are transfected with expression vectors that direct the expression of HG20,  $\text{GABA}_\text{B}\text{R1a}$  or  $\text{GABA}_\text{B}\text{R1b}$ , and the promiscuous G-protein in the cells.

15 The conditions under which step (b) of the method is practiced are conditions that are typically used in the art for the study of protein-ligand interactions: *e.g.*, physiological pH; salt conditions such as those represented by such commonly used buffers as PBS or in tissue culture media; a temperature of about 4°C to about 55°C.

20 In a particular embodiment of the above-described method, the promiscuous G-protein is selected from the group consisting of G $\alpha$ 15 or G $\alpha$ 16. Expression vectors containing G $\alpha$ 15 or G $\alpha$ 16 are known in the art. See, *e.g.*, Offermanns; Buhl et al., 1993, FEBS Lett. 323:132-134; Amatruda et al., 1993, J. Biol. Chem. 268:10139-10144.

25 The above-described assay can be easily modified to form a method to identify antagonists of the  $\text{GABA}_\text{B}$  receptor. Such a method is also part of the present invention and comprises:

- (a) providing cells that express HG20,  $\text{GABA}_\text{B}\text{R1a}$  or  $\text{GABA}_\text{B}\text{R1b}$ , and a promiscuous G-protein;
- 30 (b) exposing the cells to a substance that is an agonist of the  $\text{GABA}_\text{B}$  receptor;
- (c) subsequently or concurrently to step (b), exposing the cells to a substance that is a suspected antagonist of the  $\text{GABA}_\text{B}$  receptor;
- (d) measuring the level of inositol phosphates in the cells;

where a decrease in the level of inositol phosphates in the cells in the presence of the suspected antagonist as compared to the level of inositol phosphates in the cells in the absence of the suspected antagonist indicates that the substance is an antagonist of the GABA<sub>B</sub> receptor.

5 In a particular embodiment of the above-described method, the agonist is an amino acid such as GABA, glutamate, glycine, or amino acid analogues such as (-)baclofen.

10 In a particular embodiment of the above-described method, the cells are eukaryotic cells. In another embodiment, the cells are mammalian cells. In other 15 embodiments, the cells are L cells L-M(TK<sup>-</sup>) (ATCC CCL 1.3), L cells L-M (ATCC CCL 1.2), HEK293 (ATCC CRL 1573), Raji (ATCC CCL 86), CV-1 (ATCC CCL 70), COS-1 (ATCC CRL 1650), COS-7 (ATCC CRL 1651), CHO-K1 (ATCC CCL 61), 3T3 (ATCC CCL 92), NIH/3T3 (ATCC CRL 1658), HeLa (ATCC CCL 2), C127I (ATCC CRL 1616), BS-C-1 (ATCC CCL 26), MRC-5 (ATCC CCL 171), or 15 Xenopus oocytes.

20 The conditions under which steps (b) and (c) of the method are practiced are conditions that are typically used in the art for the study of protein-ligand interactions: *e.g.*, physiological pH; salt conditions such as those represented by such commonly used buffers as PBS or in tissue culture media; a temperature of about 4°C to about 55°C.

25 In a particular embodiment of the above-described method, the cells are transfected with expression vectors that direct the expression of HG20, GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b, and the promiscuous G-protein in the cells.

30 In a particular embodiment of the above-described method, the promiscuous G-protein is selected from the group consisting of G $\alpha$ 15 or G $\alpha$ 16.

In particular embodiments of the above-described methods, HG20 has an amino acid sequence of SEQ.ID.NO.:2.

In other embodiments of the above-described methods, HG20 comprises an amino acid sequence selected from the group consisting of:

30 SEQ.ID.NO.:2;  
Positions 9-941 of SEQ.ID.NO.:2;  
Positions 35-941 of SEQ.ID.NO.:2;  
Positions 36-941 of SEQ.ID.NO.:2;  
Positions 38-941 of SEQ.ID.NO.:2;

Positions 39-941 of SEQ.ID.NO.:2;

Positions 42-941 of SEQ.ID.NO.:2;

Positions 44-941 of SEQ.ID.NO.:2;

Positions 46-941 of SEQ.ID.NO.:2;

Positions 52-941 of SEO.ID.NO.:2; and

Positions 57-941 of SEQ.ID.NO.:2.

5 Positions 52-941 of SEQ.ID.NO.:2; and  
Positions 57-941 of SEQ.ID.NO.:2.

In other embodiments, GABA<sub>B</sub>R1a is murine GABA<sub>B</sub>R1a and has

amino acid sequence SEQ.ID.NO.:20. In other embodiments, GABABR1a is rat

10 Nature 386:239-246. In other embodiments, GABA<sub>B</sub>R1b is rat GABA<sub>B</sub>R1b and has the amino acid sequence reported in Kaupmann et al., 1997, Nature 386:239-246. In other embodiments, GABA<sub>B</sub>R1a is human GABA<sub>B</sub>R1a and has an amino acid sequence selected from the group consisting of: SEQ.ID.NO.:21 and the protein encoded by SEQ.ID.NO.:23.

15 While the above-described methods are explicitly directed to testing whether "a" substance is an agonist or antagonist of the GABA<sub>B</sub> receptor, it will be clear to one skilled in the art that such methods can be adapted to test collections of substances, *e.g.*, combinatorial libraries, to determine whether any members of such collections are activators or inhibitors of the GABA<sub>B</sub> receptor. Accordingly, the use  
20 of collections of substances, or individual members of such collections, as the substance in the above-described methods is within the scope of the present invention.

The present invention includes pharmaceutical compositions comprising agonists and antagonists of GABA<sub>B</sub> receptors that have been identified by the above-described methods. The agonists and antagonists are generally combined with pharmaceutically acceptable carriers to form pharmaceutical compositions. Examples of such carriers and methods of formulation of pharmaceutical compositions containing agonists and antagonists and carriers can be found in Remington's Pharmaceutical Sciences. To form a pharmaceutically acceptable composition suitable for effective administration, such compositions will contain a therapeutically effective amount of the agonists and antagonists.

Therapeutic or prophylactic compositions are administered to an individual in amounts sufficient to treat or prevent conditions where GABAB receptor activity is abnormal. The effective amount can vary according to a variety of factors such as the individual's condition, weight, gender, and age. Other factors include the

mode of administration. The appropriate amount can be determined by a skilled physician.

Compositions can be used alone at appropriate dosages. Alternatively, co-administration or sequential administration of other agents can be desirable.

5        The compositions can be administered in a wide variety of therapeutic dosage forms in conventional vehicles for administration. For example, the compositions can be administered in such oral dosage forms as tablets, capsules (each including timed release and sustained release formulations), pills, powders, granules, elixirs, tinctures, solutions, suspensions, syrups and emulsions, or by injection.

10      Likewise, they can also be administered in intravenous (both bolus and infusion), intraperitoneal, subcutaneous, topical with or without occlusion, or intramuscular form, all using forms well known to those of ordinary skill in the pharmaceutical arts.

15      Advantageously, compositions can be administered in a single daily dose, or the total daily dosage can be administered in divided doses of two, three or four times daily. Furthermore, compositions can be administered in intranasal form via topical use of suitable intranasal vehicles, or via transdermal routes, using those forms of transdermal skin patches well known to those of ordinary skill in that art. To be administered in the form of a transdermal delivery system, the dosage administration will, of course, be continuous rather than intermittent throughout the dosage regimen.

20      The dosage regimen utilizing the compositions is selected in accordance with a variety of factors including type, species, age, weight, sex and medical condition of the patient; the severity of the condition to be treated; the route of administration; the renal, hepatic and cardiovascular function of the patient; and the particular composition thereof employed. A physician of ordinary skill can readily determine and prescribe the effective amount of the composition required to prevent, counter or arrest the progress of the condition. Optimal precision in achieving concentrations of composition within the range that yields efficacy without toxicity requires a regimen based on the kinetics of the composition's availability to target sites. This involves a consideration of the distribution, equilibrium, and elimination of a composition.

Agonists and antagonists identified by the above-described methods are useful in the same manner as well-known agonists and antagonists of other GABAB receptors. For example, (-) baclofen is a known agonist of GABAB

receptors and, in racemic form, is a clinically useful muscle relaxant known as LIORESAL® (Bowery & Pratt, 1992, Arzneim.-Forsch./Drug Res. 42:215-223 [Bowery & Pratt]). Similarly, the agonists and antagonists of GABA<sub>B</sub> receptors identified by the methods of the present invention are expected to be useful as muscle relaxants. Bowery & Pratt, at Table 1, page 219, list the therapeutic potential of GABA<sub>B</sub> receptor agonists and antagonists. For agonists, the therapeutic potential is said to include use as muscle relaxants and anti-asthmatics. For antagonists, the therapeutic potential is said to include use as antidepressants, anticonvulsants, nootropics, and anxiolytics. Additionally, at page 220, left column, Bowery & Pratt list some additional therapeutic uses for the GABA<sub>B</sub> receptor agonist (-) baclofen: treatment of trigeminal neuralgia and reversal of ethanol withdrawal symptoms. Given the wide range of utility displayed by known agonists and antagonists of GABA<sub>B</sub> receptors, it is clear that those skilled in the art would consider the agonists and antagonists identified by the methods of the present invention to be pharmacologically useful. In addition, it is believed that such agonists and antagonists will also be useful in the treatment of epilepsy, neuropsychiatric disorders, and dementias.

When screening compounds in order to identify potential pharmaceuticals that specifically interact with a target receptor, it is necessary to ensure that the compounds identified are as specific as possible for the target receptor. To do this, it is necessary to screen the compounds against as wide an array as possible of receptors that are similar to the target receptor. Thus, in order to find compounds that are potential pharmaceuticals that interact with receptor A, it is necessary not only to ensure that the compounds interact with receptor A (the “plus target”) and produce the desired pharmacological effect through receptor A, it is also necessary to determine that the compounds do not interact with receptors B, C, D, etc (the “minus targets”). In general, as part of a screening program, it is important to have as many minus targets as possible (see Hodgson, 1992, Bio/Technology 10:973-980, at 980). HG20 protein, DNA encoding HG20 protein, GABA<sub>B</sub>R1a protein, DNA encoding GABA<sub>B</sub>R1a protein, and recombinant cells that have been engineered to express HG20 protein and GABA<sub>B</sub>R1a protein have utility in that they can be used as “minus targets” in screens design to identify compounds that specifically interact with other G-protein coupled receptors, *i.e.*, non-GABA<sub>B</sub> receptors.

The present invention also includes antibodies to the HG20 protein. Such antibodies may be polyclonal antibodies or monoclonal antibodies. The antibodies of the present invention are raised against the entire HG20 protein or against suitable antigenic fragments of the protein that are coupled to suitable carriers, 5 *e.g.*, serum albumin or keyhole limpet hemocyanin, by methods well known in the art. Methods of identifying suitable antigenic fragments of a protein are known in the art. See, *e.g.*, Hopp & Woods, 1981, Proc. Natl. Acad. Sci. USA 78:3824-3828; and Jameson & Wolf, 1988, CABIOS (Computer Applications in the Biosciences) 4:181-186. Particularly suitable peptides are: amino acids 357-371 of SEQ.ID.NO.:2 and 10 amino acids 495-511 of SEQ.ID.NO.:2. Also, anti-peptide antisera can be generated by immunization of New Zealand White rabbits with a KLH-conjugation of a 20 amino acid synthetic peptide corresponding to residues 283-302 of HG20 (GWYEPSWWEQVHTEANSSRC) (a portion of SEQ.ID.NO.:2).

For the production of polyclonal antibodies, HG20 protein or an 15 antigenic fragment, coupled to a suitable carrier, is injected on a periodic basis into an appropriate non-human host animal such as, *e.g.*, rabbits, sheep, goats, rats, mice. The animals are bled periodically and sera obtained are tested for the presence of antibodies to the injected antigen. The injections can be intramuscular, intraperitoneal, subcutaneous, and the like, and can be accompanied with adjuvant.

For the production of monoclonal antibodies, HG20 protein or an 20 antigenic fragment, coupled to a suitable carrier, is injected into an appropriate non-human host animal as above for the production of polyclonal antibodies. In the case of monoclonal antibodies, the animal is generally a mouse. The animal's spleen cells are then immortalized, often by fusion with a myeloma cell, as described in Kohler & 25 Milstein, 1975, Nature 256:495-497. For a fuller description of the production of monoclonal antibodies, see Antibodies: A Laboratory Manual, Harlow & Lane, eds., Cold Spring Harbor Laboratory Press, 1988.

Gene therapy may be used to introduce HG20 polypeptides into the 30 cells of target organs. Nucleotides encoding HG20 polypeptides can be ligated into viral vectors which mediate transfer of the nucleotides by infection of recipient cells. Suitable viral vectors include retrovirus, adenovirus, adeno-associated virus, herpes virus, vaccinia virus, and polio virus based vectors. Alternatively, nucleotides encoding HG20 polypeptides can be transferred into cells for gene therapy by non-viral techniques including receptor-mediated targeted transfer using ligand-nucleotide

conjugates, lipofection, membrane fusion, or direct microinjection. These procedures and variations thereof are suitable for *ex vivo* as well as *in vivo* gene therapy. Gene therapy with HG20 polypeptides will be particularly useful for the treatment of diseases where it is beneficial to elevate HG20 activity.

5 The following non-limiting examples are presented to better illustrate the invention.

#### EXAMPLE 1

##### Cloning and sequencing of HG20

10 A cDNA fragment encoding full-length HG20 can be isolated from a human fetal brain cDNA library by using the polymerase chain reaction (PCR) employing the following primer pair:

15 HG20.F139 5'-CCGTTCTGAGCCGAGCCG -3' (SEQ.ID.NO.:3)  
HG20.R3195 5'-TCCGCAGCCAGAGCCGACAG-3' (SEQ.ID.NO.:4)

The above primer pair is meant to be illustrative only. Those skilled in the art would recognize that a large number of primer pairs, based upon SEQ.ID.NO.:1, could also be used.

20 PCR reactions can be carried out with a variety of thermostable enzymes including but not limited to AmpliTaq, AmpliTaq Gold, Vent polymerase. For AmpliTaq, reactions can be carried out in 10 mM Tris-Cl, pH 8.3, 2.0 mM MgCl<sub>2</sub>, 200 μM for each dNTP, 50 mM KCl, 0.2 μM for each primer, 10 ng of DNA template, 0.05 units/μl of AmpliTaq. The reactions are heated at 95°C for 3 minutes and then cycled 35 times using the cycling parameters of 95°C, 20 seconds, 62°C, 20 25 seconds, 72°C, 3 minutes. In addition to these conditions, a variety of suitable PCR protocols can be found in PCR Primer, A Laboratory Manual, edited by C.W. Dieffenbach and G.S. Dveksler, 1995, Cold Spring Harbor Laboratory Press.

30 A suitable cDNA library from which a clone encoding HG20 can be isolated would be a random primed fetal brain cDNA library consisting of approximately 4.0 million primary clones constructed in the plasmid vector pBluescript (Stratagene, LaJolla, CA). The primary clones of such a library can be

subdivided into pools with each pool containing approximately 20,000 clones and each pool can be amplified separately.

By this method, a cDNA fragment (SEQ.ID.NO.:1) encoding an open reading frame of 941 amino acids (SEQ.ID.NO.:2) is obtained. This cDNA fragment 5 can be cloned into a suitable cloning vector or expression vector. For example, the fragment can be cloned into the mammalian expression vector pcDNA3.1 (Invitrogen, San Diego, CA). HG20 protein can then be produced by transferring an expression vector containing SEQ.ID.NO.:1 or portions thereof into a suitable host cell and growing the host cell under appropriate conditions. HG20 protein can then be 10 isolated by methods well known in the art.

Alternatively, other cDNA libraries made from human tissues that express HG20 RNA can be used with PCR primers HG20.F139 and HG20.R3195 in order to amplify a cDNA fragment encoding full-length HG20. Suitable cDNA 15 libraries would be those prepared from cortex, cerebellum, testis, ovary, adrenal gland, thyroid, or spinal cord.

As an alternative to the above-described PCR method, a cDNA clone encoding HG20 can be isolated from a cDNA library using as a probe oligonucleotides specific for HG20 and methods well known in the art for screening cDNA libraries with oligonucleotide probes. Such methods are described in, *e.g.*, 20 Sambrook et al., 1989, *Molecular Cloning: A Laboratory Manual*; Cold Spring Harbor Laboratory, Cold Spring Harbor, New York; Glover, D.M. (ed.), 1985, *DNA Cloning: A Practical Approach*, MRL Press, Ltd., Oxford, U.K., Vol. I, II. Oligonucleotides that are specific for HG20 and that can be used to screen cDNA libraries are:

25

HG20.F46	5'-GGGATGATCATGGCCAGTGC-3' (SEQ.ID.NO.:5)
HG20.R179	5'-GGATCCATCAAGGCCAAAGA-3' (SEQ.ID.NO.:6)
HG21.F43	5'-GCCGCTGTCTCCTCCTGA-3' (SEQ.ID.NO.:7)
HG21.R251	5'-TTGGTTCACACTGGTGACCGA-3' (SEQ.ID.NO.:8)
30 HG20.R123	5'-TTCACCTCCCTGCTGTCTTG-3' (SEQ.ID.NO.:9)
HG20.F1100	5'-CAGGCGATTCCAGTTCACTCA-5' (SEQ.ID.NO.:10)
HG20.F1747	5'-GAACCAAGCCAGCACATCCC-3' (SEQ.ID.NO.:11)
HG20.R54	5'-CCTCGCCATACAGAACTCC-3' (SEQ.ID.NO.:12)
HG20.R75	5'-GTGTCATAGAGCCGCAGGTC-3' (SEQ.ID.NO.:13)

HG20.F139 5'-CCGTTCTGAGCCGAGCCG-3' (SEQ.ID.NO.:3)  
 HG20.R3195 5'-TCCGCAGCCAGAGCCGACAG-3' (SEQ.ID.NO.:4)

Membrane-spanning proteins, such as GABA<sub>B</sub> receptors, when first  
 5 translated generally possess an approximately 16 to 40 amino acid segment known as  
 a signal sequence. Signal sequences direct the nascent protein to be transported  
 through the endoplasmic reticulum membrane, following which signal sequences are  
 cleaved from the protein. Signal sequences generally contain from 4 to 12  
 hydrophobic residues but otherwise possess little sequence homology. The Protein  
 10 Analysis tool of the GCG program (Genetics Computer Group, Madison, Wisconsin),  
 a computer program capable of identifying likely signal sequences, was used to  
 examine the N terminus of HG20. Several likely candidates for cleavage sites which  
 would generate mature HG20 protein, *i.e.*, protein lacking the signal sequence, were  
 identified. The results are shown in Figure 3.

15

#### EXAMPLE 2

##### Expression of HG20 in normal and diseased adrenal tissue

Northern blots were performed to measure the amount of HG20 RNA  
 in normal and diseased adrenal tissue. The results are shown in Table 2 below. The  
 20 amount of the approximately 6.5 kb HG20 transcript is shown normalized to the  
 amount of  $\beta$ -actin transcript.

Table 2

<u>Pathology</u>	<u>Profile</u>	<u>HG20</u>	<u>Actin</u>	<u>HG20</u>
		<u>RNA</u>	<u>RNA</u>	<u>/actin</u>
Pheochromocytoma	M, 30 yr	0.47	0.74	0.64
Adrenal carcinoma cortex	M, 69 yr	0.61	0.80	0.76
Adrenal adenoma cortex	M, 69 yr	0.62	1.15	0.54
Normal Adrenal	M, 26 yr	1.00	1.00	1.00

25

The results shown in Table 2 indicate that HG20 expression is decreased in diseased states of the adrenal gland. Thus, increasing the concentration of HG20 in such diseased states is likely to be pharmacologically useful. Accordingly, one skilled in the art would expect agonists of HG20 to be 5 pharmacologically useful.

### EXAMPLE 3

#### Tissue distribution of various HG20 RNA transcripts

Table 3, below, shows the results of experiments to measure the 10 amount of HG20 RNA transcripts of various lengths in various tissues. The results shown were derived from a multiple tissue Northern blot that was hybridized overnight in expressHyb solution (Clontech). Washing conditions were: 0.1X SSC, 0.1% SDS, at 60°C. A 32P-random primer labelled Eco RI fragment containing the full-length native 15 HG20 DNA was used as a hybridization probe. The greater the number of plus signs in a particular tissue, the greater was the amount of HG20 RNA detected in that tissue.

Table 3

Tissue	6.5 kb	4.5 kb	4.0 kb	1.8 kb
cerebellum	++	+		
cerebral cortex	++++	+		
medulla	+	+		
occipital pole	+	+		
frontal lobe	+++	+		
temporal lobe	+++	+		
putamen	++	+		
spinal cord n=2	++	+		
amygdala	+++			
caudate nucleus	+	+		
corpus callosum	+	+		
hippocampus	++	+		
whole brain	+++	+		
substantia nigra	+	+		
subthalamic nucleus	+	+		
thalamus	++	+		
spleen		+		
thymus n=2		++		
prostate		++		
testis n=2	++	+	+++	
ovary		++	+	+
small intestine n=2		++		
colon (mucosal lining)		++		
peripheral blood leucocytes		++		
stomach n=2	+	+		
thyroid n=2	++	++++		
lymph node		+		
trachea		++		
adrenal gland	+++	+++	+	++++
bone marrow		++		
heart	+	++		
brain	+++++			
placenta		+		
lung		+		
liver		+		
skeletal muscle	+	++		
kidney		+		
pancreas	+	+		
adrenal medulla	+++			+
adrenal cortex	++++		++	++

The distribution of HG20 RNA shown in Table 3 suggests that HG20  
 5 mediates activities of the central and peripheral nervous system.

## EXAMPLE 4

Distribution of HG20 mRNA in brain

Using in situ hybridisation, the distribution of HG20 mRNA in squirrel monkey brain was studied. Antisense oligonucleotide probes to HG20 were generated 5 on an Applied Biosystems Model 394 DNA synthesizer and purified by preparative polyacrylamide electrophoresis. Probe 1: 5'ATC-TGG-GTT-TGT-TCT-CAG-GGT-GAT-GAG-CTT-CGG-CAC-GAA-TAC-CAG 3' (SEQ.ID.NO.:14); Probe2: 5' GCT-CTG-TGA-TCT-TCA-TTC-GCA-GGC-GAT-GGT-TTT-CTG-ACT-GTA-GGC 3' (SEQ.ID.NO.:15). Each oligonucleotide was 3'-end labelled with 10  $[^{35}\text{S}]$  deoxyadenosine 5'-(thiotriphosphate) in a 30:1 molar ratio of  $^{35}\text{S}$ -isotope:oligonucleotide using terminal deoxynucleotidyl transferase for 15 min at 37°C in the reaction buffer supplied (Boehringer). Radiolabelled oligonucleotide was separated from unincorporated nucleotides using Sephadex G50 spin columns. The specific activities of the labelled probes in several labelling reactions varied from 1.2- 15  $2.3 \times 10^9$  cpm/mg. Squirrel monkey brains were removed and fresh frozen in 1 cm blocks. 12 mm sections were taken and fixed for *in situ* hybridisation. Hybridisation of the sections was carried out according to the method of Sirinathsinghji et al., 1993, Neuroreports 4:175-178. Briefly, sections were removed from alcohol, air dried and 5  $\times 10^5$  cpm of each  $^{35}\text{S}$ -labelled probe (both oligonucleotides) in 100 ml of 20 hybridisation buffer was applied to each slide. Labelled "antisense" probe was also used in the presence of an excess (100x) concentration of unlabelled antisense probe to define non-specific hybridisation. Parafilm coverslips were placed over the sections which were incubated overnight (about 16 hr) at 37°C. Following 25 hybridisation the sections were washed for 1 hr at 57°C in 1xSSC, then rinsed briefly in 0.1xSSC, dehydrated in a series of alcohols, air dried, and exposed to Amersham Hyperfilm bmax X-ray film. Autoradiographs were analyzed using a MCID computerized image analysis system (Image Research Inc., Ontario, Canada).

Highest levels of mRNA for HG20 were found in the hippocampus (dentate gyrus, CA3, CA2, and CA1). High levels were also seen in cortical regions 30 (frontal, cingulate, temporal parietal, entorhinal, and visual) and the cerebellum, although medial septum, thalamic nuclei (medial-dorsal and lateral posterior), lateral geniculates, red nucleus, reticular formation, and griseum points all show expression

of message. While there are many similarities with the distribution reported for the GABA<sub>B</sub> receptor mRNA in rat, one marked difference is that expression of HG20 mRNA in the monkey caudate and putamen is below the level of detection while cortical levels are high. In the rat, the GABA<sub>B</sub> receptor mRNA appears equally 5 expressed in striatum as in cortex. Figure 4 illustrates these results.

#### EXAMPLE 5

##### Attempted recombinant expression of full-length HG20 protein

Following the cloning of HG20 DNA, attempts were made to express 10 full-length HG20 protein (941 amino acids) using various eukaryotic cell lines and expression vectors. The cell lines that were used were: COS-7 cells, HEK293 cells, and frog melanophores. The expression vectors that were used to attempt to express the full-length HG20 protein were: pCR3.1 and pcDNA3.1 (Invitrogen, San Diego, CA) and pciNEO (promega)

15 All of the attempts to express full-length HG20 described above were unsuccessful. See, *e.g.*, Figure 7, second bar from the left, marked "HG20." See also Figure 5A, lane 1. Although the reason for these failures is not known, it is possible that the highly GC rich nature of the region of the HG20 mRNA that encodes amino acids 1-51 results in the formation of secondary structure in the mRNA that impedes 20 translation. It was only after the construction of an expression vector that encodes a truncated HG20 protein, lacking the first 51 amino acids, that HG20 was successfully expressed. Figure 5A-B shows the results of the successful expression of an HG20 protein having amino acids 52-941. It is expected that expression of HG20 proteins having amino acids 53-941, 54-941, 55-941, *etc.*, could be accomplished in a similar 25 manner. It is also expected that expression of HG20 proteins having the above-described amino termini but having different carboxyl termini could be accomplished in a similar manner as well. Thus, the expression of an HG20 protein having an amino terminus as listed above and having a truncated carboxyl terminus could be accomplished. Alternatively, the carboxyl terminus could be fused to non-HG20 30 amino acid sequences, forming a chimeric HG20 protein. It is also possible to express HG20 having an amino terminus listed above as a chimeric protein with non-HG20 sequences fused to the amino terminus.

Figure 5A shows the expression of amino acids 52-941 of HG20 as part of a chimeric or fusion protein with the FLAG epitope fused to the amino terminus of the HG20 sequences in a coupled *in vitro* transcription/translation experiment. Figure 5B shows the expression of amino acids 52-941 of HG20 as part 5 of a chimeric or fusion protein with the FLAG epitope fused to the amino terminus of the HG20 sequences in COS-7 cells and melanophores. The expression vector used in this experiment was pcDNA3.1. The expression constructs used in Figure 5A-B also encoded a cleavable signal sequence from the influenza hemagglutinin gene that has been shown to facilitate the membrane insertion of G-protein coupled receptors 10 (Guan et al., 1992, J. Biol. Chem. 267:21995-21998) and the fusion proteins were detected with anti-FLAG antibody. The expression constructs had also been engineered to contain a Kozak consensus sequence prior to the initiating ATG. The amino acid sequences of the hemagglutinin signal sequence and the FLAG epitope 15 were:

15 [MKTIIALSYIFCLVFA] [DYKDDDDK] SEQ.ID.NO:17  
HA signal peptide      FLAG epitope

20 Amino acids 57-941 have been expressed in mammalian cells as part of a chimeric protein. A chimeric construct of HG20 was made that consisted of bases -224 to 99 of the bovine GABA<sub>A</sub>  $\alpha 1$  gene, a sequence encoding the c-myc 25 epitope tag (amino acid residues 410-419 of the human oncogene product c-myc), a cloning site encoding the amino acid asparagine, and DNA encoding residues 57-941 of HG20. The resultant chimeric protein has the amino acid sequence shown below, with the construct cloned into pcDNA1.1Amp (Invitrogen, San Diego, CA).

30 \_\_\_\_\_Bovine alpha 1 signal seq\_\_\_\_\_ c-myc \_\_\_\_\_  
MKKSPGLSDYLWAWTFLSTLTGRSYGQPSLQD EQKLISEEDL N  
\_res. 57-941 HG20\_  
SIMGLMPLT... (SEQ.ID.NO.:18)

The three periods “...” indicate that the chimeric protein sequence extends until amino acid 941 of HG20.

The cell surface expression of this construct was verified using a cell surface ELISA technique. Briefly, HEK293 cells were seeded at ~1x10<sup>5</sup> cells per well in a 24 well tissue culture plate and allowed to adhere for 24 hours. Each well was transfected with a total of 1  $\mu$ g of DNA. In addition to tagged and un-tagged HG20 constructs, c-myc tagged GABA<sub>A</sub>  $\alpha$ 1 was transfected with GABA<sub>A</sub>  $\beta$ 1 as a positive control for cell surface expression. Two days after transfection, the cells were assayed for surface expression of the c-myc epitope using the 9E10 monoclonal antibody raised to the c-myc epitope, followed by HRP (horse radish peroxidase) conjugated anti-mouse antibody (Promega) and colormetric development using K-Blue (Bionostics). The results are shown in Figure 7. Figure 7 demonstrates that when HG20 is part of a chimeric protein, it can be expressed well in mammalian cells but that when attempts are made to express full-length HG20 (amino acids 1-941) directly, *i.e.*, not as part of a chimeric protein, essentially no expression is observed.

15 EXAMPLE 6

Construction of Full Length Murine GABA<sub>B</sub>R1a Coding Region

Using a combination of TFASTX (Pearson et al., 1997, Genomics 46:24-36) and TBLASTX (Altschul et al., 1997, Nucleic Acids Res. 25:3389-3402) searching programs against dbEST: Database of Expressed Sequence Tags (URL 20 <http://www.ncbi.nlm.nih.gov/dbEST/index.html>), we identified partial cDNA clones in the EST collection which encoded murine GABA<sub>B</sub>R1a using the rat GABA<sub>B</sub> receptor subunit cDNAs (GenBank Accession Numbers Y10369 and Y10370) as probe sequences (Kaupmann et al., 1997, Nature 386:239-246). Two of these ESTs (IMAGE Consortium clone identification numbers 472408 and 319196) were 25 obtained (Research Genetics, Birmingham, Ala). The DNA sequences of both cDNA clones were determined using standard methods on an ABI 373a automated sequencer (Perkin-Elmer-Applied Biosystems, Foster City, CA).

The partial cDNAs were assembled by long accurate PCR using the following oligonucleotides: 472408 sense: 5' - GC GAATTC GGTACC ATG CTG 30 CTG CTG CTG CTG GTG CCT - 3' (SEQ.ID.NO.:24), 472408 antisense: 5' - GG GAATTC TGG ATA TAA CGA GCG TGG GAG TTG TAG ATG TTA AA - 3' (SEQ.ID.NO.:25), 319196 sense: 5' - CCA GAATTC CCA GCC CAA CCT GAA

CAA TC - 3' (SEQ.ID.NO.:26), 319196 antisense: 5' - CG GCGGCCGC TCA CTT  
GTA AAG CAA ATG TA - 3' (SEQ.ID.NO.:27) which amplified two fragments  
corresponding to the 5' 2,100 basepairs and 3' 1,000 basepairs of the murine  
GABABR1a coding region. The PCR conditions were 200 ng of cDNA template, 2.5  
5 units of Takara LA Taq (PanVera, Madison, WI), 25 mM TAPS (pH 9.3), 50 mM  
KCl, 2.5 nM MgCl<sub>2</sub>, 1 mM 2-mercaptoethanol, 100 mM each dNTP and 1 mM each  
primer with cycling as follows 94°C 1 min, 9 cycles of 98°C for 20 seconds, 72°C-  
56°C (decreases 2°C per cycle), 72°C for 30 seconds, followed by 30 cycles of 98°C  
for 20 seconds, 60°C for 3 minutes. A final extension at 72°C for 10 minutes was  
10 performed. PCR products were cloned into the TA-Cloning vector pCRII-TOPO  
(Invitrogen, San Diego, CA) following the manufacturers directions. Cloned PCR  
products were confirmed by DNA sequencing. To form full-length cDNA, the  
pCINeo mammalian expression vector was digested with EcoRI and NotI. The EcoRI  
fragment from PCR cloning of 472408 and the EcoRI/NotI product from PCR cloning  
15 of 319196 were ligated in a three part ligation with digested pCINeo vector. The  
resulting clones were screened by restriction digestion with SstI which cuts once in  
the vector and once in the 472408 derived fragment. The resulting expression clone  
is 2,903 basepairs in length. The overall cDNA length, including untranslated  
sequences, inferred from the full length of the two ESTs is 4,460 basepairs.

20

## EXAMPLE 7

Preparation of membrane fractions

P2 membrane fractions were prepared at 4°C as follows. Tissues or  
cells were washed twice with cold PBS, collected by centrifugation at 100xg for 7  
25 min, and resuspended in 10 ml of buffer A: 5 mM Tris-HCl, 2 mM EDTA containing  
(1X) protease inhibitor cocktail Complete® tablets (Boehringer Mannheim), pH 7.4 at  
4°C. Tissues or cells were disrupted by polytron homogenization, centrifuged at  
100xg for 7 min to pellet unbroken cells and nuclei, and the supernatant collected.  
The resulting pellet was homogenized a second time in 10 ml of buffer A, centrifuged  
30 as described above and supernatant fractions saved. The pooled S1 supernatant was  
centrifuged at high speed (27 000xg for 20 min) and the pellet was washed once with  
buffer A, centrifuged (27 000xg for 20 min) and resuspended in buffer A to make the

P2 membrane fraction, and stored at -80°C. Protein content was determined using the Bio-Rad Protein Assay Kit according to manufacturer instructions.

#### EXAMPLE 8

##### 5 Receptor filter-binding assays

Competition of [<sup>125</sup>I]CGP71872 binding experiments were performed with ~7 µg P2 membrane protein and increasing concentrations of cold ligand (10-12-10<sup>-3</sup> M). The concentration of radioligand used in the competition assays was 1 nM (final). Each concentration was examined in duplicate and incubated for 2 hours at 10 22°C in the dark in a total volume of 250 µL binding buffer: 50 mM Tris-HCl, 2.5 mM CaCl<sub>2</sub> (pH 7.4) with (1X) protease inhibitor cocktail Complete® tablets. Bound ligand was isolated by rapid filtration through a Brandel 96 well cell harvester using Whatman GF/B filters. Data were analyzed by nonlinear least-squares regression using the computer-fitting program GraphPad Prism version 2.01 (San Diego).

15

#### EXAMPLE 9

##### Photoaffinity labelling

P2 membranes were resuspended in binding buffer and incubated in the dark with 1 nM final concentration [<sup>125</sup>I]CGP71872 (2200 Ci/mmol) in a final 20 volume of 1 ml for 2 h at 22°C. The membranes were centrifuged at 27,000xg for 10 min and the pellet was washed in ice-cold binding buffer, centrifuged at 27,000xg for 20 min, resuspended in 1 ml of ice-cold binding buffer, and exposed on ice 2 inches from 360 nm ultraviolet light for 10 min. Photolabelled membranes were washed, pelleted by centrifugation, and solubilized in sample buffer (50 mM Tris-HCl pH 6.5, 25 10% SDS, 10% glycerol, and 0.003% bromophenol blue with 10% 2-mercaptopethanol). Samples were electrophoresed on precast NOVEX 10% Tris-glycine gels, fixed, dried, and exposed to Kodak XAR film with an intensifying screen at -70°C.

## EXAMPLE 10

Immunoprecipitation and immunoblotting of GABA<sub>B</sub> receptors

Digitonin solubilized FLAG-tagged HG20 receptors were immunoprecipitated with a mouse anti-FLAG M2 antibody affinity resin (Kodak IBI) and immunoblot analysis conducted as previously described (Ng et al., 1996, Biochem. Biophys. Res. Comm. 227:200-204). Following washing of the immunoprecipitate, the pellet was resuspended in SDS sample buffer and subjected to SDS-PAGE and immunoblotted with affinity purified GABA<sub>B</sub>R1a-specific antibodies 1713.1 (raised against the peptide acetyl-DVNSRRDILPDYELKLC-amide (a portion of SEQ.ID.NO.:20)) and 1713.2 (raised against the peptide acetyl-CATLHNPTRVKLFEK-amide (a portion of SEQ.ID.NO.:20)).

## EXAMPLE 11

Melanophore functional assay

Growth of *Xenopus laevis* melanophores and fibroblasts was performed as described previously (Potenza et al., 1992, Anal. Biochem. 206:315-322). The cells (obtained from Dr. M.R. Lerner, Yale University) were collected by centrifugation at 200xg for 5 min at 4°C, and resuspended at 5 x 10<sup>6</sup> cells per ml in ice cold 70% PBS, pH 7.0. DNA encoding the relevant GPCR was transiently transfected into melanophores by electroporation using a BTX ECM600 electroporator (Genetronics, Inc., San Diego, CA). To monitor the efficiency of transfection, two internal control GPCRs were used independently (pcDNA1amp-cannabinoid 2 and pcDNA3-thromboxane A2; (Lerner, 1994, Trends Neurosci. 17:142-146)). Cells were electroporated using the following settings: capacitance of 325 microfarad, voltage of 450 volts, and resistance of 720 ohms. Following electroporation, cells were mixed with fibroblast-conditioned growth medium and plated onto flat bottom 96 well microtiter plates (NUNC). 24 hrs after the transfection, the media was replaced with fresh fibroblast-conditioned growth media and incubated for an additional day at 27°C prior to assaying for receptor expression. For Gs/Gq-coupling responses (resulting in pigment dispersion), cells were incubated

in 100  $\mu$ l of 70% L-15 media containing 15 mM HEPES, pH 7.3, and melatonin (0.8 nM final concentration) for 1 hr in the dark at room temperature, and then incubated in the presence of melatonin (0.8 nM final concentration) for 1 h in the dark at room temperature to induce pigment aggregation. For Gi-coupled responses (resulting in 5 pigment aggregation), cells were incubated in the presence of 100  $\mu$ l/well of 70% L-15 media containing 2.5% fibroblast-conditioned growth medium, 2 mM glutamine, 100  $\mu$ g /ml streptomycin, 100 units/ml penicillin and 15 mM HEPES, pH 7.3, for 30 min in the dark at room temperature to induce pigment dispersion. Absorbance 10 readings at 600 nm were measured using a Bio-Tek Elx800 Microplate reader (ESBE Scientific) before (Ai) and after (Af) incubation with ligand (GABA; 1.5 hr in the dark at room temperature).

#### EXAMPLE 12

15 Stable and transient transfections and determination of cAMP response in HEK293 cells

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HG20 and murine GABA<sub>B</sub>R1a cDNAs were subcloned into pcDNA3.1 (Invitrogen, San Diego, CA) and used to transfect HEK293 cells. Stably expressing cells were identified after selection in geneticin (0.375 mg/ml) by dot blot analysis. For co-expression experiments, the stable cell lines hgb2-42 (expressing 20 HG20) and rgb1a-50 (expressing murine GABA<sub>B</sub>R1a) were transiently transfected with murine GABA<sub>B</sub>R1a and HG20, respectively, in pcDNA3.1 and cells were assayed for cAMP responses.

Wild-type HEK293 cells, or HEK293 cells stably and transiently expressing HG20 and murine GABA<sub>B</sub>R1a receptors were lifted in 1X PBS, 2.5 mM 25 EDTA, counted, pelleted and resuspended at  $1.5 \times 10^5$  cells per 100 $\mu$ l in Krebs-Ringer-Hepes medium (Blakely et al., 1991, Anal. Biochem. 194:302-308), 100 mM Ro 20-1724 (RBI) and incubated at 37°C for 20 min. 100  $\mu$ l of cells was added to 100  $\mu$ l of prewarmed (37°C, 10 min) Krebs-Ringer-Hepes medium, 100 mM Ro 20-1724 without or with agonist and/or 10  $\mu$ M forskolin. Incubations with GABA 30 included 100  $\mu$ M aminoxyacetic acid (a GABA transaminase inhibitor) to prevent breakdown of GABA and 100  $\mu$ M nipecotic acid to block GABA uptake. Following a 20 min incubation at 37°C, the assay was terminated by setting the cells on ice and

centrifuging at 2,000 rpm for 5 min at 4°C. 175 ml of assay solution was removed and replaced with 175 ml of 0.1 N hydrochloric acid, 0.1 mM calcium chloride and cells were set on ice for 30 min and then stored at -20°C. cAMP determinations were made using a solid phase modification (Maidment et al., 1989, *Neurosci.* 33:549-557) of the cAMP radioimmunoassay described by Brooker et al. 1979, *Adv. Cyclic Nucl. Res.* 10:1-33) and previously reported in Clark et al., 1998, *Mol. Endocrinol.* 12:193-206). Immulon II removawells (Dynatech; Chantilly, VA) were coated overnight with 100 µl of protein G (1mg/ml in 0.1M NaHCO<sub>3</sub>, pH 9.0) at 4°C. Prior to use, protein G-coated plates were rinsed with PBS-gelatin-Tween (phosphate buffered saline containing 0.1% gelatin, 0.2% Tween-20) 3 times quickly, and then once for 30 minutes. Following the rinse with PBS-gelatin-Tween, the RIA was set up by adding 100 µl 50 mM sodium acetate, pH 4.75, cAMP standards or aliquots from treated cells, 5,000-7,000 cpm <sup>125</sup>I-succinyl cAMP, and 25 µl of a sheep antibody to cAMP diluted in 50 mM sodium acetate, pH 4.75 (Atto instruments; dilution of stock to 2.5x10<sup>-5</sup>, determined empirically) to the plates in a final volume of 175 µl. Plates were incubated 2 hr at 37°C or overnight at 4°C, rinsed 3 times with sodium acetate buffer, blotted dry, and then individual wells were broken off and bound radioactivity was determined in a gamma counter.

20

## EXAMPLE 13

*In situ* hybridization for co-localization experiments

Preparation of rat brain sections, prehybridization and hybridization of rat brain slices was performed as described previously (Bradley et al., 1992, *J. Neurosci.* 12:2288-2302; <http://intramural.nimh.nih.gov/lcmr/snge/Protocol.html>). 25 Adjacent coronal rat brain sections were hybridized with labeled antisense and sense riboprobes directed against HG20 (GenBank accession number AF058795) or murine GABA<sub>B</sub>R1a.

HG20 probes were generated by amplification of HG20 with JC216 (T3 promotor/primer and bases 1172-1191) paired with JC217 (T7 promotor/primer and bases 1609-1626) or with JC218 (T3 promotor/primer and bases 2386-2405) paired with JC219 (T7 promotor/primer and bases 2776-2793):

(JC216: cgcgcaattaaccctactaaaggACAACAGCAAACGTTCAGGC (SEQ.ID.NO.:28);  
 JC217: ggcgttaatcgc actcactatagggCATGCCTATGATGGTGAG (SEQ.ID.NO.:29);  
 JC218: cgcgcaattaaccctactaaagg CTGAGGACAAACCTGACGC  
 5 (SEQ.ID.NO.:30);  
 JC219: ggcgttaatcgcactcactatagggGATGTC TTCTATGGGTC; (SEQ.ID.NO.:31)).  
 Murine GABA<sub>B</sub>R1a probes were generated by amplification of murine GABA<sub>B</sub>R1a with JC160 (T3 promotor/primer and bases 631-648) paired with JC161 (T7 promotor/primer and bases 1024-1041);  
 10 (JC160: cgcgcaattaaccctactaaaggAAGCTTATCCACCACGAC (SEQ.ID.NO.:32);  
 JC161: ggcgttaa tacgactcactatagggAGCTGGATCCGAGAAGAA (SEQ.ID.NO.:33)).  
 For colocalization experiments, murine GABA<sub>B</sub>R1a probes were labeled with digoxigenin-UTP and detected using a peroxidase-conjugated antibody to digoxigenin and TSA amplification involving biotinyl tyramide and subsequent 15 detection with streptavidin-conjugated fluorescein. HG20 probes were radiolabelled (<http://intramural.nimh.nih.gov/lcmr/snge/Protocol.html>). For individual hybridizations, murine GABA<sub>B</sub>R1a and HG20 riboprobes were radiolabeled with <sup>35</sup>S-UTP and detected as described previously (Bradley et al., 1992, J. Neurosci. 12:2288-2302; <http://intramural.nimh.nih.gov/lcmr/snge/Protocol.html>). Brain slices 20 were either hybridized with individual radiolabelled probes or, for colocalization studies, simultaneously with probes to both murine GABA<sub>B</sub>R1a and HG20 receptors. Detection of the radiolabeled HG20 probe was performed after detection of the digoxigenin-labeled *rgb1* probe on the same brain slices.

25

## EXAMPLE 14

Construction of N-terminal and C-terminal fragments of murine GABA<sub>B</sub>R1a

The N-terminal fragment of murine GABA<sub>B</sub>R1a, comprising amino acid positions 1-625, was generated by PCR. The coding sequence of the N-terminal fragment was amplified by using primer pairs: NFP-CJ7843F139 (5'- ACC ACT 30 GCT AGC ACC GCC ATG CTG CTG CTG CTG C -3'; SEQ.IS.NO.:34) and NRP-CJ7844 (3'- GG GTG CGA GCA ATA TAG GTC TTA AGG GTC GGC CGC CGG CGT CAC CA -5'; ; SEQ.IS.NO.:35). Similarly, the C-terminal fragment,

amino acid positions 588-942, was generated by PCR using primer pairs: CFP-CJ7845 (5'- ACC ACT GCT AGC ACC GCC ATG CAG AAA CTC TTT ATC TCC GTC TCA GTT CTC TCC AGC-3'; ; SEQ.IS.NO.:36) and CRP-CJ7846 (3'- CAG CTC ATG TAA ACG AAA TGT TCA CTC GCC GGC CGC CGG CGT CAC CA- 5'; ; SEQ.IS.NO.:37). PCR reactions were carried out using the Advantage-HF PCR kit (Clontech, Paolo Alto, CA) with 0.2 ng of murine GABA<sub>B</sub>R1a DNA as the template, and 10  $\mu$ M of each primer according to manufacturer instructions. The PCR conditions were as follows: precycle denaturation at 94°C for 1 min, and then 35 cycles at 94°C (15 s), annealing and extension at 72°C (3 min), followed by a final extension for 3 min at 72°C. The PCR products, N-gb 1a and C-gb 1a DNA, flanked by Nhe1 and Not1 sites, were digested and subcloned into the Nhe1/Not1 site of pcDNA3.1 (Invitrogen, San Diego, Ca).

#### EXAMPLE 15

15 Cell culture and preparation of membrane fractions for binding experiments using N-terminal and C-terminal GABA<sub>B</sub>R1a fragments

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20 COS-7 cells (ATCC) were cultured in DMEM, 10% bovine serum, 25 mM HEPES, and antibiotics and transiently transfected with murine gb1a/pcDNA3.1 (encoding full-length GABA<sub>B</sub>R1a), N-gb 1a/pcDNA3.1 (encoding the N-terminal fragment of GABA<sub>B</sub>R1a; see Example 14) or C-gb 1a/pcDNA3.1 (encoding the C-terminal fragment of GABA<sub>B</sub>R1a; see Example 14) using Lipofectamine reagent (Gibco BRL) following the conditions recommended by the manufacturer. At 48 h post-transfection, P2 membrane fractions were prepared at 4°C as follows: Cells were washed twice with cold PBS, collected by centrifugation at 100xg for 7 min, and 25 resuspended in 10 ml of buffer A: 5 mM Tris-HCl, 2 mM EDTA containing (1X) protease inhibitor cocktail Complete<sup>®</sup> tablets (Boehringer Mannheim), pH 7.4 at 4°C. Cells were disrupted by polytron homogenization, centrifuged at 100xg for 7 min to pellet unbroken cells and nuclei, and the supernatant collected. The resulting pellet was homogenized a second time in 10 ml of buffer A, centrifuged as described above 30 and supernatant fractions saved. The pooled S1 supernatant was centrifuged at high speed (27,000xg for 20 min) and the pellet was washed once with buffer A, centrifuged (27,000xg for 20 min), resuspended in buffer A to make the P2 membrane

fraction, and stored at -80°C. Protein content was determined using the Bio-Rad Protein Assay Kit according to manufacturer instructions.

#### EXAMPLE 16

5 *In vitro* transcription/translation of GABA<sub>B</sub>R1a and N-terminal and C-terminal  
fragments

---

10 *In vitro* transcription coupled translation reactions were performed in the presence of [<sup>35</sup>S]-methionine in the TNT Coupled Reticulocyte Lysate system (Promega, WI) using the pcDNA3.1 plasmid containing the full-length GABA<sub>B</sub>R1a,  
15 N-gb1a, and C-gb1a DNAs. Translation products were analysed by electrophoresis on 8-16% Tris-Glycine gradient gels (Novex pre-cast gel system) under denaturing and reducing conditions. Gels were fixed, treated with enlightening fluid (NEN), dried and exposed to Kodak X-AR film at -70°C for 4 to 24 h. Analysis of the results of these *in vitro* transcription coupled translation reactions confirmed that the  
15 constructs whose production is described in Example 14 directed the expression of the appropriate GABA<sub>B</sub>R1a fragments (see Figure 17A).

#### EXAMPLE 17

20 Immunoblot analysis for experiments with N-terminal and C-terminal fragments of  
GABA<sub>B</sub>R1a

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25 The expression of full-length and N-terminal and C-terminal GABA<sub>B</sub>R1a fragments *in vivo* was confirmed by immunoblot analysis. Membranes were solubilized in SDS sample buffer consisting of 50 mM Tris-HCl pH 6.5, 10% SDS, 10% glycerol, and 0.003% bromophenol blue with 10% 2-mercaptoethanol and separated on SDS-PAGE. The full-length receptor and N-terminal fragment were detected using affinity purified rabbit GABA<sub>B</sub>R1a polyclonal antibody 1713.1 (acetyl-DVNSRRDILPDYELKLC-amide; a portion of SEQ.ID.NO.:20) and 1713.2 (acetyl-CATLHNPTRVKLFEK-amide; a portion of SEQ.ID.NO.:20) (Quality Control Biochemicals (Hopkinton, MA). The C-terminal fragment was detected  
30 using a GABA<sub>B</sub>R1a antibody raised against the C-terminal tail of the receptor

(acetyl-PSEPPDRLSCDGSRVHLLYK-amide; SEQ.ID.NO.:20) (Chemicon Int., Inc., Canada).

#### EXAMPLE 18

5 Receptor filter-binding assays for experiments with N-terminal and C-terminal  
fragments of GABA<sub>B</sub>R1a

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10 Competition of [<sup>125</sup>I] CGP71872 binding experiments were performed with ~7 µg P2 membrane protein and increasing concentrations of cold ligand (10-12-10<sup>-3</sup> M). The concentration of radioligand used in the competition  
assays was 1 nM (final). Each concentration was examined in duplicate and  
15 incubated for 2 hr at 22°C in the dark in a total volume of 250 µL binding buffer: 50 mM Tris-HCl, 2.5 mM CaCl<sub>2</sub> (pH 7.4) with (1X) protease inhibitor cocktail Complete<sup>®</sup> tablets. Bound ligand was isolated by rapid filtration through a Brandel 96 well cell harvester using Whatman GF/B filters. Data were analyzed by nonlinear least-squares regression using the computer-fitting program GraphPad Prism version 2.01 (San Diego).

#### EXAMPLE 19

20 Photoaffinity labeling for experiments with N-terminal and C-terminal fragments of  
GABA<sub>B</sub>R1a

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25 P2 membranes were resuspended in binding buffer, and incubated in the dark with 1 nM final concentration [<sup>125</sup>I]CGP71872 (2200 Ci/mmol) in a final volume of 1 ml for 2 h at 22°C. The membranes were centrifuged at 27, 000xg for 10 min and the pellet was washed in ice-cold binding buffer, centrifuged at 27, 000xg for 20 min and resuspended in 1 ml of ice-cold binding buffer and exposed on ice 2 inches from 360 nm ultraviolet light for 10 min. photolabelled membranes were washed and membranes pelleted by centrifugation and solubilized in sample buffer (50 mM Tris-HCl pH 6.5, 10% SDS, 10% glycerol, and 0.003% bromophenol blue with 10% 2-mercaptoethanol). Samples were electrophoresed on precast NOVEX

10% Tris-glycine gels, fixed, dried, and exposed to Kodak XAR film with an intensifying screen at -70°C.

#### EXAMPLE 20

5 Construction of the FLAG epitope-tagged HG20 and detection of expression in vitro and in COS-1 cells

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The FLAG epitope-tagged HG20 receptor subunit was constructed by PCR using a sense primer encoding a modified influenza hemagglutinin signal sequence (MKTIIIALSYIFCLVFA; a portion of SEQ.ID.NO.:17) (Jou et al., 1980, 10 Cell 19:683-696) followed by an antigenic FLAG epitope (DYKDDDDK; a portion of SEQ.ID.NO.:17) and DNA encoding amino acids 52-63 of HG20 and an antisense primer encoding amino acids 930-941 of the HG20 in a high-fidelity PCR reaction with HG20/pCR 3.1 as a template. HG20/pCR 3.1 is a plasmid that contains full-length HG20 (SEQ.ID.NO.:2) cloned into pCR3.1. The nucleotide sequences of the 15 sense and antisense primers are: sense: 5'-GCC GCT AGC GCC ACC ATG AAG ACG ATC ATC GCC CTG AGC TAC ATC TTC TGC CTG GTA TTC GCC GAC TAC AAG GAC GAT GAT GAC AAG AGC AGC CCG CCG CTC TCC ATC ATG GGC CTC ATG CCG CTC-3', (SEQ.ID.NO.:38); antisense: 5'-GCC TCT AGA TTA CAG GCC CGA GAC CAT GAC TCG GAA GGA GGG TGG CAC-3'. 20 (SEQ.ID.NO.:39). The PCR conditions were: precycle denaturation at 94°C for 1 min, 94°C for 30 sec, annealing and extension at 72°C for 4 min for 25 cycles, followed by a 7 min extension at 72°C . The PCR product, SF-HG20 DNA, flanked by NheI and XbaI sites was subcloned into the NheI/XbaI site of pcDNA3.1 (Invitrogen, San Diego, Ca) to give rise to the expression construct SF- 25 HG20/pcDNA3.1. The sequence of this construct was verified on both strands.

The SF-HG20 receptor was expressed in an *in vitro* coupled transcription/translation reaction using the TNT Coupled Reticulocyte Lysate system (Promega, WI) in the presence of [<sup>35</sup>S]methionine according to the manufacturer instructions. Radiolabeled proteins were analyzed by electrophoresis on 8-16% Tris- 30 Glycine gradient gels (Novex pre-cast gel system) under denaturing and reducing conditions. Gels were fixed and treated with Enlightening fluid (NEN), dried and exposed to Kodak X-AR film at -70°C.

COS-1 cells (ATCC, CRL 1650) were cultured in DMEM, 10% bovine serum, 25 mM HEPES, pH 7.4, and 10 units/mL penicillin- 10  $\mu$ g/mL streptomycin. Transient transfection of COS-1 cells with SF-HG20/pcDNA 3.1 was carried out using Lipofectamine reagent (Gibco BRL) following the conditions  
5 recommended by the manufacturer. At 48 h post-transfection, crude membranes were prepared and receptors were solubilized with digitonin and immunoprecipitated with anti-FLAG M2 affinity gel resin (IBI) under previously described conditions (Ng et al., 1993). The immunoprecipitate was washed and solubilized in SDS sample buffer, sonicated, electrophoresed, and blotted on to nitrocellulose membrane as described  
10 (Ng et al., 1993). The FLAG-tagged HG20 receptor was detected using an anti-FLAG antibody (Santa Cruz Biotech., Inc.) by following a chemiluminescence protocol of the manufacturer (NEN).

#### EXAMPLE 21

15 Kir channel activity in *Xenopus* oocytes

With the following modifications, *Xenopus* oocytes were isolated as described (Hébert et al., 1994, Proc. R. Soc. Lond. B 256:253-261) from live frogs supplied by Boreal, Inc. After a brief (10 min) hypertonic shock with 125 mM potassium phosphate pH 6.5, oocytes were allowed to recover in Barth's solution for  
20 1-2 hr. cDNA constructs for human Kir 3.1, Kir 3.2 channel isoforms (generous gifts from Dr. Hubert Van Tol, University of Toronto), and Gi $\alpha$ 1 (a generous gift of Dr. Maureen Linder, Washington University) were linearized by restriction enzymes and purified using Geneclean (Bio 101). Murine GABA<sub>B</sub>R1a or FLAG-HG20 clones were subcloned into pT7TS (a generous gift of Dr. Paul Krieg, University of Texas)  
25 before linearization and transcription. Capped cRNA was made using T7 RNA polymerase and the mMessage mMachine (Ambion). Individual oocytes were injected with 5-10 ng (in 25-50 nL) of Kir3.1 and Kir3.2 constructs with mRNAs for murine GABA<sub>B</sub>R1a or FLAG-HG20 and in combination with Gi $\alpha$ 1 as well. Kir currents were also evaluated in oocytes co-injected with Kir3.1, Kir3.2, murine GABA<sub>B</sub>R1a  
30 and FLAG-HG20 mRNAs. Currents were recorded after 48 hr. Standard recording solution was KD-98, 98 mM KCl, 1 mM MgCl<sub>2</sub>, 5 mM K-HEPES, pH 7.5, unless otherwise stated. Microelectrodes were filled with 3 M KCl and had resistances of 1-

3 MW and 0.1-0.5 MW for voltage and current electrodes, respectively. In addition, current electrodes were backfilled with 1% agarose (in 3M KCl) to prevent leakage as described (Hébert et al., 1994, Proc. R. Soc. Lond. B 256:253-261). Recordings were made at room temperature using a Geneclamp 500 amplifier (Axon Instruments).

5 Oocytes were voltage clamped and perfused continuously with different recording solutions. Currents were evoked by 500 msec voltage commands from a holding potential of -10 mV, delivered in 20 mV increments from -140 to 60 mV to test for inward rectifying potassium currents. Data were recorded at a holding potential of -80 mV and drugs were added to the bath with a fast perfusion system. Data collection

10 and analysis were performed using pCLAMP v6.0 (Axon Instruments) and Origin v4.0 (MicroCal) software. For subtraction of endogenous and leak currents, records were obtained in ND-96, 96 mM NaCl, 2 mM KCl, 1 mM MgCl<sub>2</sub>, 5 mM Na-HEPES and these were subtracted from recordings in KD-98 before further analysis.

15

## EXAMPLE 22

Radiation Hybrid mapping of HG20

Radiation hybrid analysis assigned the HG20 gene to chromosome 9, placing it 4.81 cR from the WI-8684 marker on the GeneBridge 4 panel of 93 RH clones of the whole human genome. Searching of the OMIM database with D9S176 and D9S287 markers proximal to the HG20 gene revealed it to map proximal to the hereditary sensory neuropathy type 1 (HSN-1) locus, a ~8 cM region flanked by D9S176 and 9S318 (Nicholson et al., 1996, Nature Genetics 13, 101-104) (Figure 20). HSN-1 is the most common form of a group of degenerative disorders of sensory neurons characterized by a progressive degeneration of dorsal root ganglion and motor neurons that lead to distal sensory loss, distal muscle wasting and weakness, and neural deafness, among a number of other neuronally related deficits (Nicholson et al., 1996, Nature Genetics 13, 101-104). FCMD (Fukuyama congenital muscular dystrophy) and DYS (dysautonomia, another type of HSN) also map to this area. Candidate gene(s) in these disorders are likely critical to the development, survival, and differentiation of neurons.

A human BAC library was screened using the EcoRI fragment containing the full-length HG20 DNA, and end-sequencing was performed on BAC

clones designated 6D18, 168K19, 486B24, and 764N4. The primer pair: ngf1t7+ (5'-AAC AGT CAA AAC CCA CCC AG-3'; SEQ.ID.NO.:40) and ngf1t7- (5'-AAC AGT TTC CAG CTG TGC CT-3'; SEQ.ID.NO.:41) were identified for radiation hybrid mapping of the HG20 gene on the GENEBRIDGE 4 panel. BAC library screening and radiation hybrid mapping were performed by Research Genetics (Huntsville, AL).

5 The present invention is not to be limited in scope by the specific embodiments described herein. Indeed, various modifications of the invention in  
10 addition to those described herein will become apparent to those skilled in the art from the foregoing description. Such modifications are intended to fall within the scope of the appended claims.

15 Various publications are cited herein, the disclosures of which are incorporated by reference in their entireties.

0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78 80 82 84 86 88 90 92 94 96 98 100

## WHAT IS CLAIMED:

1. An isolated DNA molecule encoding an HG20 polypeptide comprising an amino acid sequence selected from the group consisting of:
  - 5 SEQ.ID.NO.:2;
  - Positions 9-941 of SEQ.ID.NO.:2;
  - Positions 35-941 of SEQ.ID.NO.:2;
  - Positions 36-941 of SEQ.ID.NO.:2;
  - Positions 38-941 of SEQ.ID.NO.:2;
  - 10 Positions 39-941 of SEQ.ID.NO.:2;
  - Positions 42-941 of SEQ.ID.NO.:2;
  - Positions 44-941 of SEQ.ID.NO.:2;
  - Positions 46-941 of SEQ.ID.NO.:2;
  - 15 Positions 52-941 of SEQ.ID.NO.:2; and
  - Positions 57-941 of SEQ.ID.NO.:2.
2. The isolated DNA molecule of claim 1 comprising a nucleotide sequence selected from the group consisting of:
  - 20 SEQ.ID.NO.:1;
  - Positions 293-3,115 of SEQ.ID.NO.:1;
  - Positions 317-3,115 of SEQ.ID.NO.:1;
  - Positions 395-3,115 of SEQ.ID.NO.:1;
  - Positions 398-3,115 of SEQ.ID.NO.:1;
  - 25 Positions 404-3,115 of SEQ.ID.NO.:1;
  - Positions 407-3,115 of SEQ.ID.NO.:1;
  - Positions 416-3,115 of SEQ.ID.NO.:1;
  - Positions 422-3,115 of SEQ.ID.NO.:1;
  - Positions 428-3,115 of SEQ.ID.NO.:1;
  - 30 Positions 446-3,115 of SEQ.ID.NO.:1; and
  - Positions 461-3,115 of SEQ.ID.NO.:1.
3. An isolated DNA molecule that hybridizes under stringent conditions to the DNA molecule of claim 2.

4. An expression vector comprising the DNA of  
claim 1.

5. A recombinant host cell comprising the expression vector of  
5 claim 4.

6. The recombinant cell of claim 5 further comprising an  
expression vector comprising DNA encoding a protein selected from the group  
consisting of:  
10

7. A protein, substantially free from other proteins, comprising an  
HG20 protein having an amino acid sequence selected from the group consisting of:  
SEQ.ID.NO.:2;  
15 Positions 9-941 of SEQ.ID.NO.:2;  
Positions 35-941 of SEQ.ID.NO.:2;  
Positions 36-941 of SEQ.ID.NO.:2;  
Positions 38-941 of SEQ.ID.NO.:2;  
Positions 39-941 of SEQ.ID.NO.:2;  
20 Positions 42-941 of SEQ.ID.NO.:2;  
Positions 44-941 of SEQ.ID.NO.:2;  
Positions 46-941 of SEQ.ID.NO.:2;  
Positions 52-941 of SEQ.ID.NO.:2; and  
Positions 57-941 of SEQ.ID.NO.:2.  
25

8. A heterodimer comprising the protein of claim 7 and a G-  
protein coupled receptor protein where the heterodimer is substantially free from  
other proteins.

30 9. The heterodimer of claim 8 where the heterodimer is held  
together by N-terminal Sushi repeats, C-terminal alpha-helical interacting domains,  
coiled-coil domains, transmembrane interactions, or disulfide bonds.

10. A polypeptide comprising a coiled-coil domain from a first GABA<sub>B</sub> receptor subunit and no other contiguous amino acid sequences longer than 5 amino acids from the first GABA<sub>B</sub> receptor subunit where the coiled-coil domain is present in the C-terminus of the GABA<sub>B</sub> receptor subunit and mediates

5 heterodimerization of the first GABA<sub>B</sub> receptor subunit with a second GABA<sub>B</sub> receptor subunit.

11. The polypeptide of claim 10 where the coiled-coil domain is selected from the group consisting of: positions 756-829 of SEQ.ID.NO.:2; positions 10 779-814 of SEQ.ID.NO.:2; positions 886-949 of SEQ.ID.NO.:21; and positions 889-934 of SEQ.ID.NO.:21.

12. An isolated DNA molecule encoding a GABA<sub>B</sub>R1a polypeptide comprising the amino acid sequence SEQ.ID.NO.:20.

15

13. A protein, substantially free from other proteins, comprising a GABA<sub>B</sub>R1a protein having the amino acid sequence SEQ.ID.NO.:20.

14. A method for determining whether a substance binds GABA<sub>B</sub> receptors and is thus a potential agonist or antagonist of the GABA<sub>B</sub> receptor that comprises:

20 (a) providing cells comprising an expression vector encoding HG20 and an expression vector encoding GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b;

(b) culturing the cells under conditions such that HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b are expressed and heterodimers of HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b are formed;

25 (c) exposing the cells to a labeled ligand of GABA<sub>B</sub> receptors in the presence and in the absence of the substance;

(d) measuring the binding of the labeled ligand to the heterodimers of HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b;

30 where if the amount of binding of the labeled ligand is less in the presence of the substance than in the absence of the substance, then the substance is a potential agonist or antagonist of GABA<sub>B</sub> receptors.

15. A method of identifying agonists and antagonists of HG20 comprising:

- (a) providing test cells by transfecting cells with:
  - (1) an expression vector that directs the expression of HG20 in the cells; and
  - (2) an expression vector that directs the expression of GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b in the cells;
- (b) exposing the test cells to a substance that is suspected of being an agonist of the GABA<sub>B</sub> receptor;
- (c) measuring the amount of a functional response of the test cells that have been exposed to the substance;
- (d) comparing the amount of the functional response exhibited by the test cells with the amount of the functional response exhibited by control cells; wherein if the amount of the functional response exhibited by the test cells differs from the amount of the functional response exhibited by the control cells, the substance is an agonist or antagonist of the GABA<sub>B</sub> receptor;

16. A method of producing functional GABA<sub>B</sub> receptors in cells comprising:

- (a) transfecting cells with:
  - (1) an expression vector that directs the expression of HG20 in the cells; and
  - (2) an expression vector that directs the expression of GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b in the cells;
- (b) culturing the cells under conditions such that heterodimers of HG20 and GABA<sub>B</sub>R1a or GABA<sub>B</sub>R1b are formed where the heterodimers constitute functional GABA<sub>B</sub> receptors.

17. An antibody that binds specifically to HG20 where HG20 has an amino acid sequence selected from the group consisting of:  
SEQ.ID.NO.:2;

5 Positions 9-941 of SEQ.ID.NO.:2;  
Positions 35-941 of SEQ.ID.NO.:2;  
Positions 36-941 of SEQ.ID.NO.:2;  
Positions 38-941 of SEQ.ID.NO.:2;  
Positions 39-941 of SEQ.ID.NO.:2;  
Positions 42-941 of SEQ.ID.NO.:2;  
Positions 44-941 of SEQ.ID.NO.:2;  
Positions 46-941 of SEQ.ID.NO.:2;  
Positions 52-941 of SEQ.ID.NO.:2; and  
10 Positions 57-941 of SEQ.ID.NO.:2.

18. A method of expressing a truncated version of HG20 protein comprising:

(a) transfecting a host cell with a expression vector that encodes an HG20 protein that has been truncated at the amino terminus;

(b) culturing the transfected cells of step (a) under conditions such that the truncated HG20 protein is expressed.

19. A chimeric HG20 protein having an amino acid sequence of  
20 HG20 selected from the group consisting of:  
    Positions 51-941 of SEQ.ID.NO.:2;  
    Positions 52-941 of SEQ.ID.NO.:2;  
    Positions 53-941 of SEQ.ID.NO.:2;  
    Positions 54-941 of SEQ.ID.NO.:2;  
25    Positions 55-941 of SEQ.ID.NO.:2;  
    Positions 56-941 of SEQ.ID.NO.:2;  
    Positions 57-941 of SEQ.ID.NO.:2; and  
    Positions 58-941 of SEQ.ID.NO.:2;  
covalently linked at the N-terminus with a non-HG20 amino acid sequence.

**TITLE OF THE INVENTION**  
**NOVEL GABA<sub>B</sub> RECEPTOR DNA SEQUENCES**

**ABSTRACT OF THE DISCLOSURE**

5           DNA encoding a novel human GABA<sub>B</sub> receptor subunit, HG20, as  
well as the protein encoded by the DNA, is provided. Also provided is DNA  
encoding a novel murine GABA<sub>B</sub> receptor subunit, GABA<sub>B</sub>R1a, as well as the  
protein encoded by the DNA. Heterodimers of HG20 protein and GABA<sub>B</sub>R1a  
protein that form a functional GABA<sub>B</sub> receptor are disclosed. Methods of identifying  
10          agonists and antagonists of the GABA<sub>B</sub> receptor are also provided.

1 CCGCCCTCCC CCGGCCGAGC TCCAGGGCTG CCGCCTAGCA GCTCCCGGG  
 51 GGAGAGCGGT TCAGAGCTCG CTCCCACCCC TTCCCGGCGT GATTGATCCG  
 101 TCACGGGCGC CTCCGCTGCC GCCGCCGCC CGCGGCCCGT TCTGAGCCGA  
 151 GCCGGAACCC TAGCCCGAGA CGGAGCCGGG GCCCCGGGCCG GCGCCATTGC  
 201 GCGGGCGCCG CGGGAAAGACC TTGGCGCGGG GCGGCAGGCC GGGCCAGGCC  
 251 ATGCGGGCCG AGTGAGCCGG CGCCCGCAGC CGCGGCCCG GCATGGCTTC  
 301 CCCGCGGAGC TCCGGGCAGC CGGGGCCGCC GCGGCCGCC CGACCGGCC  
 351 CCGCGCGCCT GCTACTGCTA CTGCTGCTGC CGCTGCTGCT GCCTCTGGCG  
 401 CCCGGGGCCT GGGGCTGGC GCAGGGGCC CGCCGCCCG CGCCCAGCAG  
 451 CCCGCGCGCTC TCCATCATGG GCCTCATGCC GCTCACCAAG GAGGTGGCCA  
 501 AGGGCAGCAT CGGGCGCGGT GTGCTCCCCG CGGTGGAACG GCCATCGAG  
 551 CAGATCCGCA ACGAGTCACT CCTGCGCCCC TACTTCCTCG ACCTGCGGCT  
 601 CTATGACACG GAGTGCAGCA ACGAAAAGG GTTAAAGGCC TTCTACGATG  
 651 CAATAAAATA CGGGCCGAAC CACTTGATGG TGTTTGGAGG CGTCTGTCCA  
 701 TCCGTCACAT CCATCATTGC AGAGTCCCTC CAAGGCTGGA ATCTGGTGCA  
 751 GCTTTCTTTT GCTGCAACCA CGCCTGTTCT AGCCGATAAG AAAAAATACC  
 801 CTTATTTCTT TCGGACCGTC CCATCAGACA ATGCGGTGAA TCCAGCCATT  
 851 CTGAAGTTGC TCAAGCACTA CCAGTGGAAAG CGCGTGGCA CGCTGACGCA  
 901 AGACGTTCAAG AGGTTCTCTG AGGTGCGGAA TGACCTGACT GGAGTTCTGT  
 951 ATGGCGAGGA CATTGAGATT TCAGACACCG AGAGCTTCTC CAACGATCCC  
 1001 TGTACCAAGTG TCAAAAAGCT GAAGGGGAAT GATGTGCGGA TCATCCTTGG  
 1051 CCAGTTTGAC CAGAAATATGG CAGCAAAAGT GTTCTGTTGT GCATACGAGG  
 1101 AGAACATGTA TGGTAGTAAA TATCAGTGGA TCATTCCGGG CTGGTACGAG  
 1151 CCTTCTTGGT GGGAGCAGGT GCACACGGAA GCCAACTCAT CCCGCTGCT  
 1201 CCGGAAGAAT CTGCTGCTG CCATGGAGGG CTACATTGGC GTGGATTTCG  
 1251 AGCCCCCTGAG CTCCAAGCAG ATCAAGACCA TCTCAGGAAA GACTCCACAG  
 1301 CAGTATGAGA GAGAGTACAA CAACAAGCGG TCAGGGCTGG GGCCCAGCAA  
 1351 GTTCCACGGG TACGCCTACG ATGGCATCTG GGTCACTGCC AAGACACTGC  
 1401 AGAGGGCCAT GGAGACACTG CATGCCAGCA GCCGGCACCA GCAGGATCCAG  
 1451 GACTTCAACT ACACGGACCA CACGCTGGC AGGATCATCC TCAATGCCAT  
 1501 GAACGAGACC AACTTCTTCG GGGTCACGGG TCAAGTTGTA TTCCGGAATG  
 1551 GGGAGAGAAT GGGGACCATT AAATTTACTC AATTCAAGA CAGCAGGGAG  
 1601 GTGAAGGTGG GAGAGTACAA CGCTGTGGCC GACACACTGG AGATCATCAA  
 1651 TGACACCAC AGGTTCCAAG GATCCGAACC ACCAAAAGAC AAGACCATCA  
 1701 TCCTGGAGCA GCTGCCAGG ATCTCCCTAC CTCTCTACAG CATCCTCTCT  
 1751 GCCCTCACCA TCCTCGGGAT GATCATGGCC AGTGTGTTTC TCTTCTTCAA  
 1801 CATCAAGAAC CGGAATCAGA AGCTCATAAA GATGTGAGT CCATACATGA  
 1851 ACAACCTTAT CATCCTTGGA GGGATGCTCT CCTATGCTTC CATATTTCTC  
 1901 TTTGGCCTTG ATGGATCCTT TGTCTCTGAA AAGACCTTG AAACACTTG  
 1951 CACCGTCAGG ACCTGGATTG TCACCGTGGG CTACACGACC GCTTTGGGG  
 2001 CCATGTTGC AAAGACCTGG AGAGTCCACG CCATCTCAA AAATGTGAAA  
 2051 ATGAAGAAGA AGATCATCAA GGACCAGAAA CTGCTGTGA TCGTGGGGGG  
 2101 CATGCTGCTG ATCGACCTGT GTATCCTGAT CTGCTGGCAG GCTGTGGACC  
 2151 CCCTGCGAAG GACAGTGGAG AAGTACAGCA TGGAGCCGGA CCCAGCAGGA

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2201 CGGGATATCT CCATCCGCC CTCCTGGAG CACTGTGAGA ACACCCATAT  
2251 GACCATCTGG CTTGGCATCG TCTATGCCCA CAAGGGACTT CTCATGTTGT  
2301 TCGGTTGTTT CTTAGCTTGG GAGACCCGCA ACGTCAGCAT CCCCAGCACTC  
2351 AACGACAGCA AGTACATCGG GATGAGTGTC TACAACGTGG GGATCATGTG  
2401 CATCATCGGG GCCGCTGTCT CCTTCCTGAC CCGGGACCAG CCCAATGTGC  
2451 AGTTCTGCAT CGTGGCTCTG GTCATCATCT TCTGCAGCAC CATCACCCCTC  
2501 TGCCCTGGTAT TCGTGCCGAA GCTCATCACC CTGAGAACAA ACCCAGATGC  
2551 AGCAACGCAG AACAGGGCAT TCCAGTTAC TCAGAACATCAG AAGAAAGAAG  
2601 ATTCTAAAAC GTCCACCTCG GTCACCAGTG TGAACCAAGC CAGCACATCC  
2651 CGCCTGGAGG GCCTACAGTC AGAAAACCAT CGCCTGCGAA TGAAGATCAC  
2701 AGAGCTGGAT AAAGACTTGG AAGAGGTAC CATGCAGCTG CAGGACACAC  
2751 CAGAAAAGAC CACCTACATT AAACAGAACCC ACTACCAAGA GCTCAATGAC  
2801 ATCCTCAACC TGGGAAACTT CACTGAGAGC ACAGATGGAG GAAAGGCCAT  
2851 TTTAAAAAAAT CACCTCGATC AAAATCCCCA GCTACAGTGG AACACAACAG  
2901 AGCCCTCTCG AACATGCAA GATCCTATAG AAGATATAAA CTCTCCAGAA  
2951 CACATCCAGC GTCGGCTGTC CCTCCAGCTC CCCATCCTCC ACCACGCCCTA  
3001 CCTCCCCATCC ATCGGAGGCG TGGACGCCAG CTGTGTCAGC CCCTGCGTCA  
3051 GCCCCCACCGC CAGCCCCCGC CACAGACATG TGCCACCCCTC CTTCCGAGTC  
3101 ATGGTCTCGG GCCTGTAAGG GTGGGGGGCC TGGGCCCGGG GCCTCCCCCG  
3151 TGACAGAACCC ACACGGGCA GAGGGGTCTG CTGCAGAAC ACTGTGGCT  
3201 CTGGCTCGGG AGAAGCTGGG CACCATGGCT GGCCTCTCAG GACCACCTCGG  
3251 ATGGCACTCA GGTGGACAGG ACGGGGCAGG GGGAGACTTG GCACCTGACC  
3301 TCGAGCCTTA TTTGTGAAGT CCTTATTTCT TCACAAAGAA GAGGAACCGA  
3351 AATGGGACGT CTTCCCTAAC ATCTGCAAAC AAGGAGGCGC TGGGATATCR  
3401 AATTCCACCA CACTGGCGGC CCGCGCTTGS TCSTAATCAT GGTATAACT  
3451 GTTCCCTGTG TTGAAATTGT TATCCGCTCC

FIG.1B

1 MASPRSSGQP GPPPPPPPPP ARLLLLLLP LLLPLAPGAW GWARGAPRPP  
51 PSSPLSIMG LMPLTKEVAK GSIGRGVLPA VELAIEQIRN ESLLRPYFLD  
101 LRLYDTECDN AKGLKAFYDA IKYGPNHLMV FGGVCPSTVS IIAESLQGN  
151 LVQLSFAATT PVLADKKYP YFFRTVPSDN AVNPAILKLL KHYQWKRVGT  
201 LTQDVQRFSE VRNDLTGVLY GEDIEISDTE SFSNDPCTSV KKLKGNDVRI  
251 ILGQFDQNMA AKVFCCAYEE NMYGSKYQWI IPGWYEPSWW EQVHTEANSS  
301 RCLRKNLAA MEGYIGVDFA PLSSKQIKTI SGKTPQQYER EYNNKRSGVG  
351 PSKFHGYAYD GIWVIAKTLQ RAMETLHASS RHQRIQDFNY TDHTLGRIIL  
401 NAMNETNFFG VTGQVVFRNG ERMGTIKFTQ FQDSREVKVG EYNAVADTLE  
451 IINDTIRFQG SEPPKDKTII LEQLRKISLP LYSILSALTI LGMIMASAFL  
501 FFNIKNRNQK LIKMSSPYMN NLIILGGMLS YASIFLFGLD GSFVSEKTFE  
551 TLCTVRTWIL TVGYTTAFGA MFAKTWRVHA IFKNVKMKKK IIKDQKLLVI  
601 VGGMLLIDLC ILICWQAVDP LRRTVEKYSM EPDPAGRDIS IRPLLEHCEN  
651 THMTIWLGIV YAYKGLLMLF GCFLAWETRN VSIPALNDSK YIGMSVYNVG  
701 IMCIIGAAVS FLTRDQPNVQ FCIVALVIIF CSTITLCLVF VPKLITLRTN  
751 PDAATQNRRF QFTQNQKKED SKTSTSUTSV NQASTSRLEG LQSENHRLRM  
801 KITELDKDLE EVTMQLQDTP EKTTYIKQNH YQELNDILNL GNFTESTDGG  
851 KAILKNHLDQ NPQLQWNTTE PSRTCKDPIE DINSPEHIQR RLSLQLPILH  
901 HAYLPSIGGV DASCVSPCVS PTASPRHRHV PPSFRVMVSG L

Sequence: LPLLLPLAPGAWG-WARGAPRPPPSSPPLSIMGLMPLTKEVAKGSIGRGVLPAVELAIEQIRNE  
 |(signal) |(mature peptide)  
 29 42

Other entries above 3.50

Score 11.1 at residue 39

Sequence: LLLLPLLLPLAPG-AWGARGAPRPPPSSPPLSIMGLMPLTKEVAKGSIGRGVLPAVELAIEQI  
 |(signal) |(mature peptide)  
 26 39

Score 8.6 at residue 38

Sequence: LLLLLPLLLPLAP-GAWGARGAPRPPPSSPPLSIMGLMPLTKEVAKGSIGRGVLPAVELAIEQ  
 |(signal) |(mature peptide)  
 25 38

Score 8.1 at residue 35

Sequence: RLLLLLLPLLLP-LAPGAWGARGAPRPPPSSPPLSIMGLMPLTKEVAKGSIGRGVLPAVELA  
 |(signal) |(mature peptide)  
 22 35

Score 7.9 at residue 36

Sequence: LLLLLLPLLLPL-APGAWGARGAPRPPPSSPPLSIMGLMPLTKEVAKGSIGRGVLPAVELAI  
 |(signal) |(mature peptide)  
 23 36

Score 6.2 at residue 9

Sequence: -QPGRPPPPPPPPPARLILLLLLPLLLPLAPGAWGARGAPRPPPSSPPLS  
 |(signal) |(mature peptide)  
 -4 9

Score 5.7 at residue 46

Sequence: LPLAPGAWGARG-APRPPPSSPPLSIMGLMPLTKEVAKGSIGRGVLPAVELAIEQIRNESLLR  
 |(signal) |(mature peptide)  
 33 46

Score 5.6 at residue 747

Sequence: ITLCLVFVPLIT-LRTNPDAATQNRRFQFTQNQKKEDSKTSTSVDNQASTSRLEGLOSENH  
 |(signal) |(mature peptide)  
 734 747

Score 5.0 at residue 44

Sequence LLLPLAPGAWGWA-RGAPRPPPSSPPLSIMGLMPLTKEVAKGSIGRGVLPAVELAIEQIRNESL  
 |(signal) |(mature peptide)  
 31 44

Score 4.9 at residue 497

FIG.3A

Sequence: ILSALTILGMIMA-SAFLFFNIKNRNQKLIKMSSPMNNLII~~LG~~GGMLS~~Y~~ASIFLFGLDGSFVSE  
|(signal) |(mature peptide)

484 497

Score 4.5 at residue 141

Sequence: LMVFGGVCPSVTS-IIAESLQGWNLVQLSFAATTPVLADKKYPYFFRTVPSDNAVNPA~~I~~ILKLL  
|(signal) |(mature peptide)

128 141

Score 4.4 at residue 734

Sequence: FCIVALVIIFCST-ITLCLVFVPKLITLRTNPDAATQNRRFQFTQNQKKEDSKTSTS~~V~~T~~S~~VNQA  
|(signal) |(mature peptide)

721 734

Score 4.1 at residue 165

Sequence: VQLSFAATTPVLA-DKKYPYFFRTVPSDNAVNPA~~I~~ILKLLKHYQWKR~~V~~G~~T~~L~~T~~QDVQR~~F~~SEVRND  
|(signal) |(mature peptide)

152 165

Score 3.6 at residue 158

Sequence: SLQGWNLVQLSFA-ATTPVLADKKYPYFFRTVPSDNAVNPA~~I~~ILKLLKHYQWKR~~V~~G~~T~~L~~T~~QDVQR  
|(signal) |(mature peptide)

145 158

**FIG.3B**

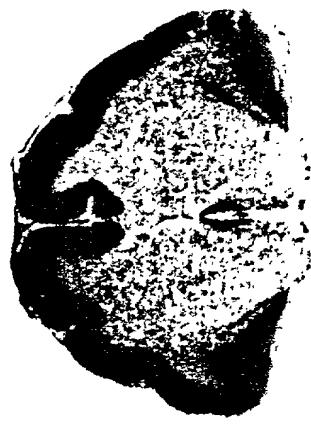
09/601582

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Distribution of mRNA for EST z43654 in squirrel monkey brain.



at level of caudate and putamen



at level of thalamus and hippocampus

FIG.4



at level of cerebellum and occipital cortex example of cold displayed

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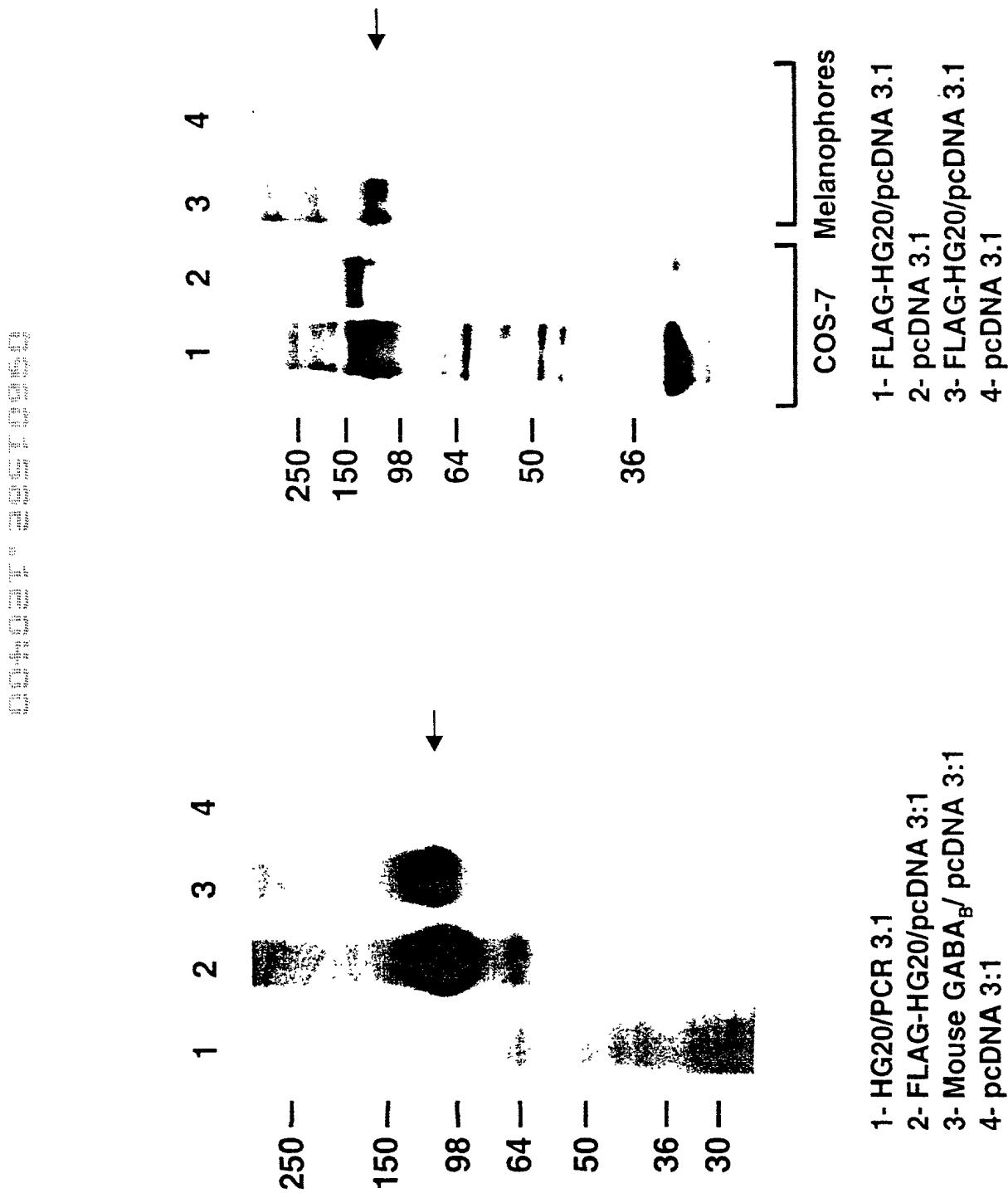


FIG. 5A

FIG. 5B

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PLTKEVAK-GSIGR-GVLPVELAIEQIRNESLLRPYFLDLRLYDTECDNAKGLKAFYDA  
.: .  
PVTPVVAQYQDMQRAGAL---MAIEQINKAGGVNGAQLEGVIYDDACDPKQAVAVANKV

IKYGPNHLMVFGGVCPSTSIIAESLQGWNLVQLSFAATPPVLADKKKPYFFRTVPSDN  
... : . . . : : : .  
VNDGVK--FVVGHVCSSSTQPATDIYEDEGVLMITPSATAPEIT-SRGYKLIFRTIGLDN

AVNPAILKLL-KHYQWKRVGTLTQDVQRFSE-VRNDLTGVLYGEDIEISDTEFS---ND  
... . . . . : . . : . : .  
MQGPVAGKFIAERYKVKTIAVL-HDKQQYGEGIATEVKTVEDAGIRVAVFEGLNAGDKD

PCTSVKKLGNDVRII-LGQFDQNM  
  . . . . . . . . . . .  
  FNLISLKKAGVQFVYFGGYHPEM

FIG. 6

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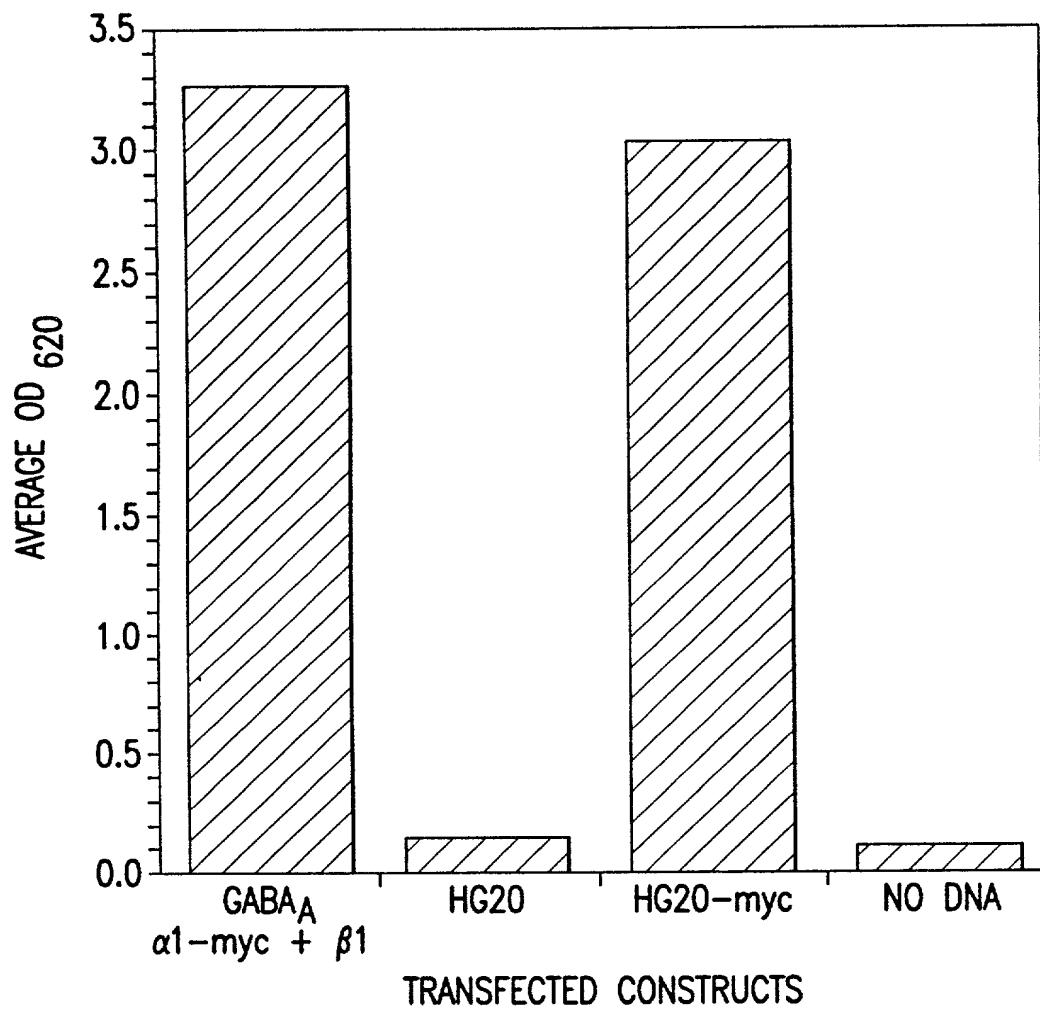


FIG.7

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GABA-BR1b	MGPGGPCTPVGMPLPLLVMAAGVAPVWASHSPHL---PRPHPRVPPHSERRAVYIGALFPMSGGP-G-GQ	69
HG20	MASPRSSGQGRPPPPPARLILLPLLPLAPGAWGARGAPRPPSSPPLSIMGLMPLTKEVAKGSIGR	75
Consensus	M.....G.P.P.....L.....R.P.P.....I.L.P.....G.G.	75
GABA-BR1b	ACQPAVEMALEDVNSRRDILDYELKLIHHD SKCDPGQATKYL YELL YNDPIKILLMPG-CSSVSTLVAEAARMW	143
HG20	GVLPAWELAIEQIRN-ESLRPYPFLDLRLYDTECDNAKGLKAFYDAIKYGPNHLMWFGGVCPSTSIIAESLQGW	149
Consensus	...PAVE.A.E.....L..Y.L.L..D..CD.....K..Y.....P.....G.C.SV....AE....W	150
GABA-BR1b	NLIVLSYGSSSPALSNRQRFPPTFFRTHPSATLHMPTRVKLFEKWGMKKIATIQQTTEVFTSTLDLEERVKEAGI	218
HG20	NLVQLSFAATTWVLADKKKKYQPFRTVPSDNAPAILKLKHYQWKRVGTLTQDVQRFSEVRNDLTGVLYGEDI	224
Consensus	NL..LS....P.L.....P.FFRT.PS.....NP...KL....W.K....T.Q....F.....DL.....I	225
GABA-BR1b	EITFRQSFSDPAVPVKNLKRQDARIIVGLFYETEARKVFCVYKERLFGKKYVWFLIGWYADNWF---KTYDPS	290
HG20	EISDTEFSNDPCTSVKKLKGNDVRILGQFDQNMMAAKVFCAYEENMYSKQWIIIPGMYEPSSWIEQVHTEANS	299
Consensus	EI....SF...DP...VK.LK...D.RII.G.F...A.KVFC..Y.E...G.KY.W...GWY...W....T...S	300
GABA-BR1b	INCTVEEMTEAVEGHITTEIVMLNPANTRISINMTSQEFVEKLTKRLKRHPEETGGFQEAPLAYDAIWALALAN	365
HG20	SRCLRKNLAAAMEGYIGVDFEPLSSKQIKITISGKTPQQY-EREYNN-KRSGVGPSKFHGYAYDGWVIAKTLQRA	372
Consensus	C.....A.EG.I.....L.....IS..T.Q...E.....KR.....F.....A.L...	375
GABA-3R1b	KTSGGGGRSGVRLEDFNYNNQTTIDQIYRAMNSSSFEVGSHVVFASGRMAWTIIEQLQGGSYKKIGYYDSTK	440
HG20	METLHASSRHQR1QDFNYTDHTLGRITLNAMNETNFFGVTGQWVFR-NGERMGTIKFTQFQDSREVKGYNAVA	446
Consensus	.....R..DFNY...T...I...AMN..F.GV.G.WVF...G.RM.....Q.Q....K.G.Y....	450
GABA-BR1b	DDLSWSKTDKWIIGSSPPADQTLVIKTFRFLSQKLFIISVSVLSSLGIVLAWVC---LSFNIIYNSHVRYIQNSQPNL	512
HG20	DTLEIINDTIRFQGSEPPKDKTII--LEQLRKISLPLYSILSALTILGMIMASAFLFFNIKMRNQKLIKMSSPYM	519
Consensus	D.L.....GS.P.....I.....L.....S.L.I.....L.FNI.N.....I.S.P..	525

FIG.8A

GABA-BR1b	NNLTAVGCSLAAAVFPLGLDGYHIGRSQFPVCQARLWILLGLFSLGYGSMFTKIMWVHTVFTKKEEEKKERK	587
HG20	NNLII1GGMLSYASIFLGLDGSFVSEKTFETLCTVRTWILTVGYTTAFTGAMFAKTMVHAIF--KNVKMK-KK1	591
Consensus	NNL...G..L..A..F..GLDG...F..C..R..W..L..G...G..MF..K..W..VH..F..K..K...K..	600
GABA-BR1b	LEPIWKLYATVGLLVGMDVLTIAIWQIVDPLHRTIETFAKEEPKEDIDVSILPQLEHCSSKKMNTWLGIFYGYKGL	662
HG20	IKDQKLLVIVGGMLLIDLCILICWQAVDPLRRRTVEKYSMPEPDAGRDISIRPLLEHCENTHMTIWLGIIVAYKGGL	666
Consensus	KL...VG...D...L...WQ..VDPL..RT.E...E.....D.SI.P.LEHC...M..WLGI.Y.YKGL	675
GABA-BR1b	LLLLGIFLAYETKSVSTEKINDHRAVGMAIYNNAVLCITAPVTMILSSQQDAAFASLAIVFSSYITLVWLFV	737
HG20	LMLFGCFLAWETRNVSIPALNDSKYIGMSVYNGIMCIGAAVSFLTRDQPNVQFCIVALVIIFCSTITLCLVFW	741
Consensus	L.L.G.FLA.ET..VS...ND...GM..YNV...C.I.A.V...Q...F...L.I.F.S.ITL...FV	750
GABA-BR1b	PKMRRLLTRGE-----W-----QSETOQDTMKTGSS-TNNNNEEKSRL--LEKE-----NRELEKI-----	784
HG20	PKLITIRTNPDAATQNRRFQFTQNQKKEDSKTSTS VTSV NQASTSRLEGQSENHRLRMKITELDKDLEEVTMQL	816
Consensus	PK..L.T.....Q.....KT..S.T..N...SRL..L..E.....LE.....LE.....	825
GABA-BR1b	--IAEKE-----ERVSE-----LHQLOQSRRQQLRSRRRHPPPTPP--DPSGG-----	820
HG20	QDTPEKTTYIKQNHQELNDILNLGNFTTESTDGGKAILKHNLDQNPQLQWNNTTEPSRTCKDPIEDINSPEHITQRR	891
Consensus	.....EK.....L...L.....QL.....P.....DP.....	900
GABA-BR1b	--LPR-GPSEPPDRLSC----DGSRVHLL---YK-----	844
HG20	LSLQLPILHHAYLPSIGGVADSCVSPCVSPTASPRHRWPPSFRVMVSGL	941
Consensus	.....LP..6.....C.....R.....	950

FIG. 8B

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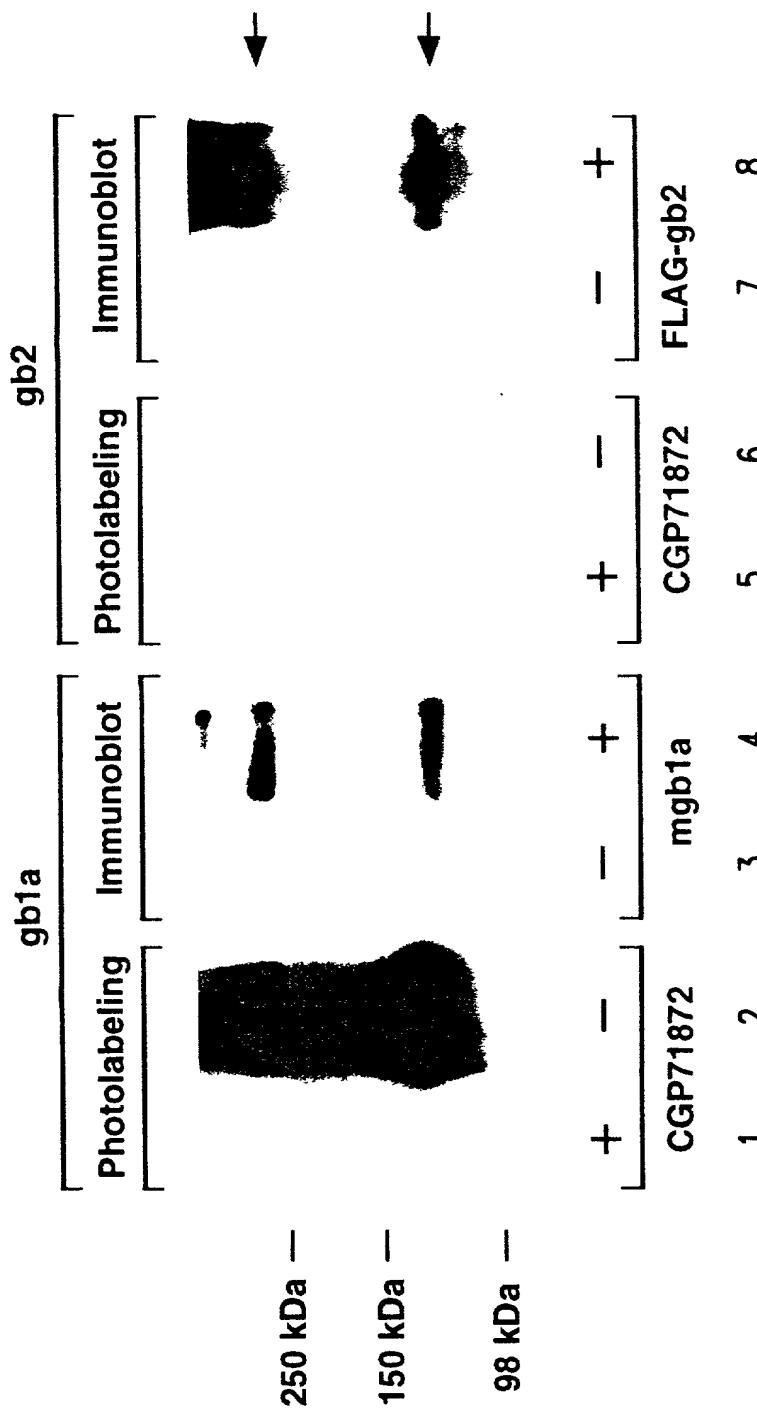


FIG. 9

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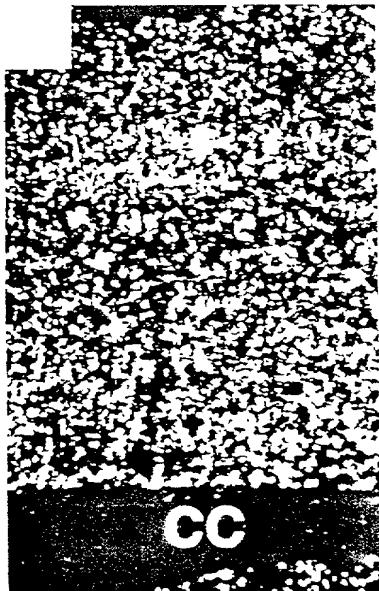


FIG.10A

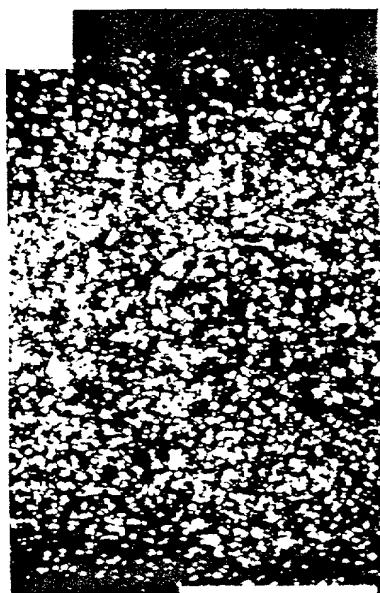


FIG.10B



FIG.10C

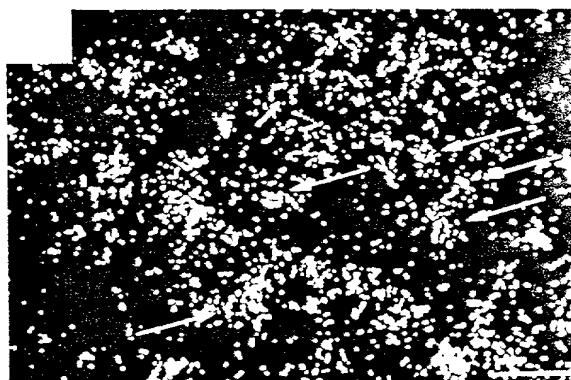


FIG.10D

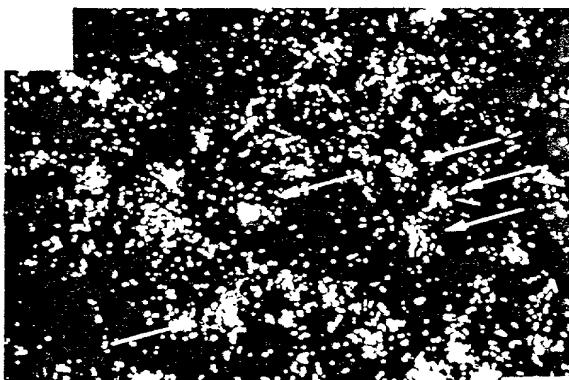


FIG.10E

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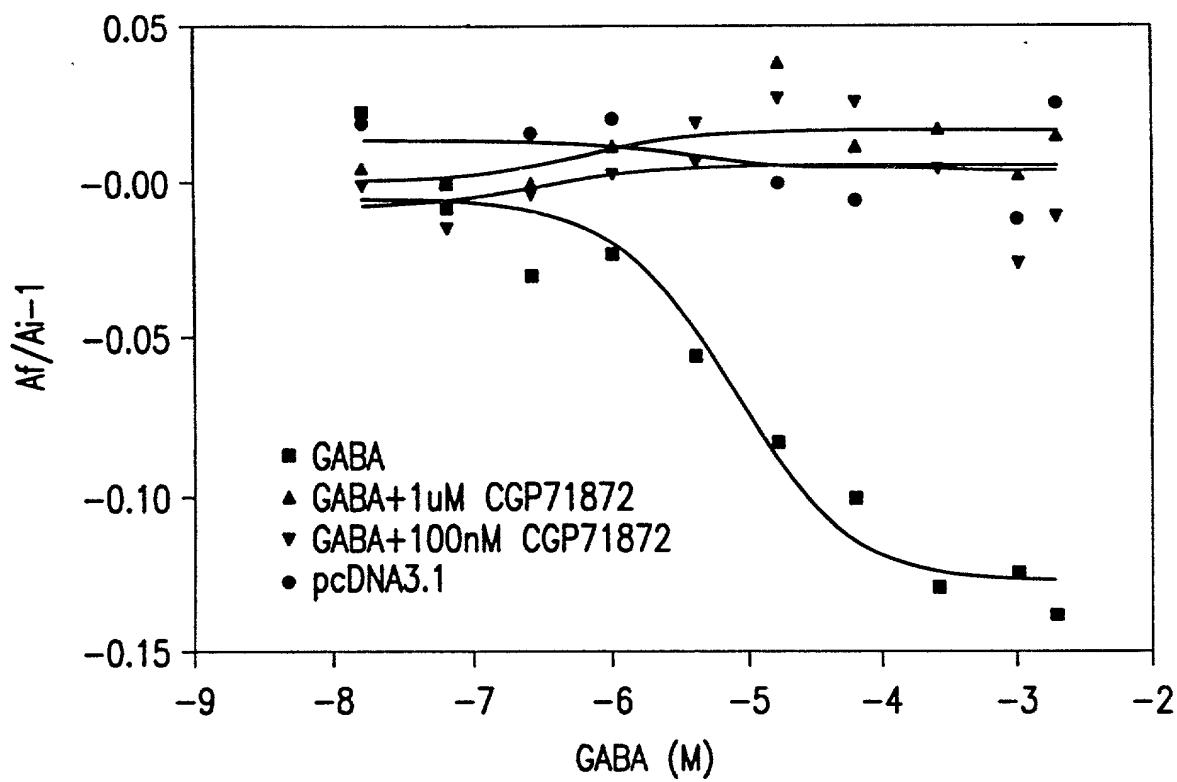


FIG. 11A

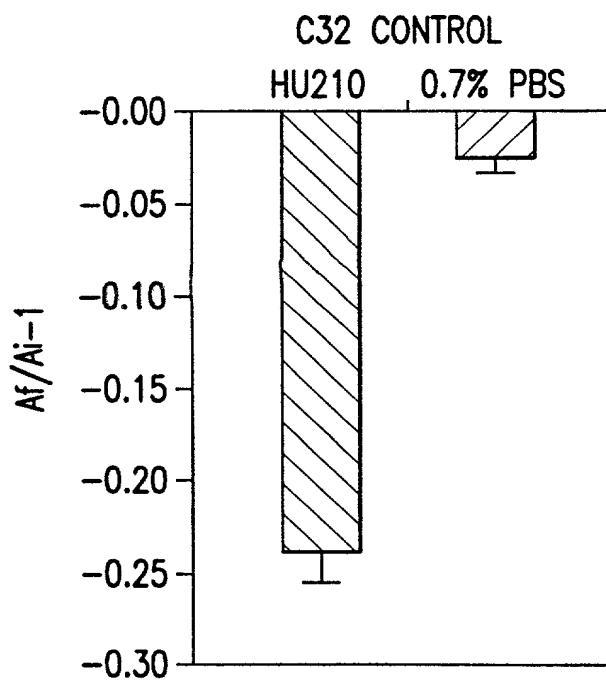


FIG. 11B

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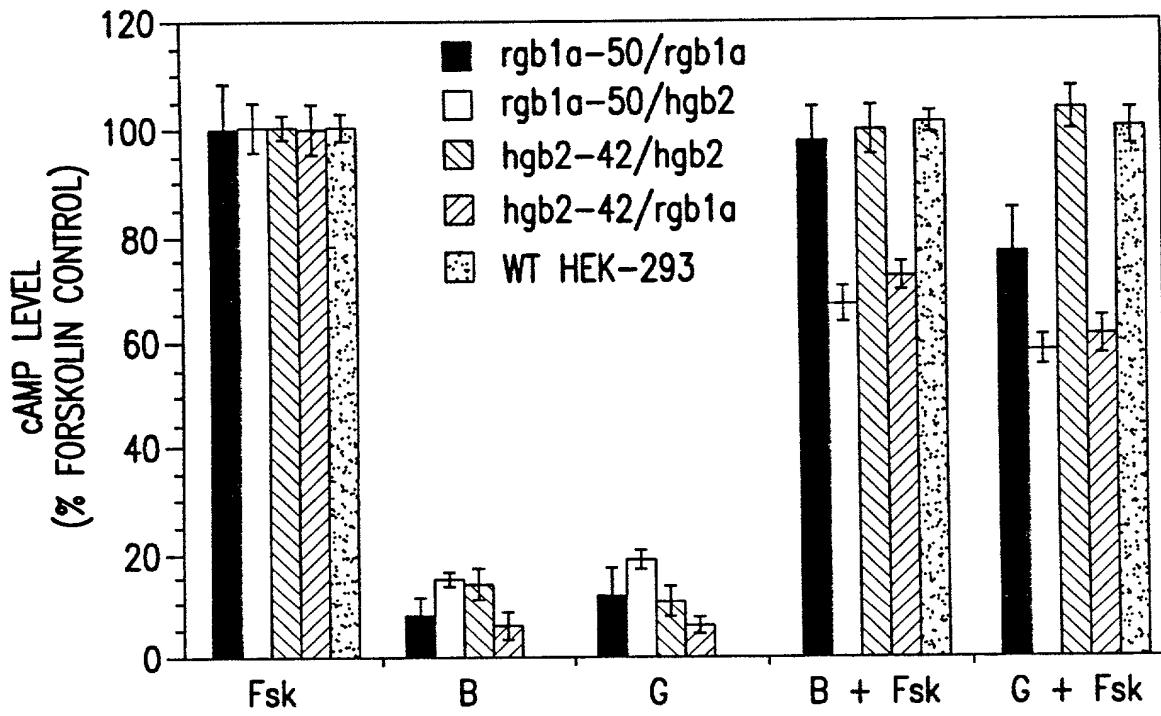


FIG. 12

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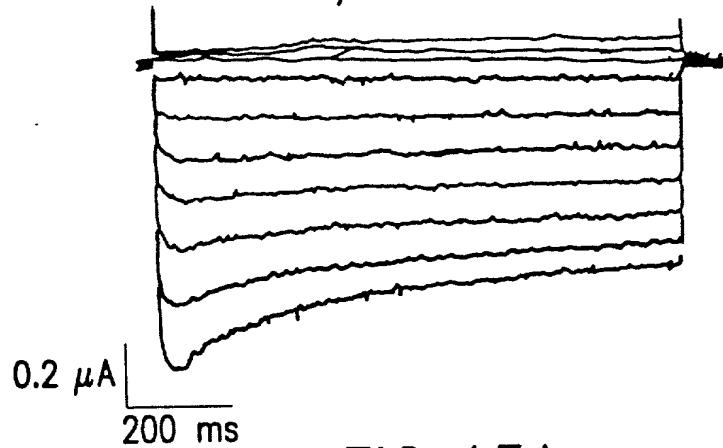


FIG. 13A

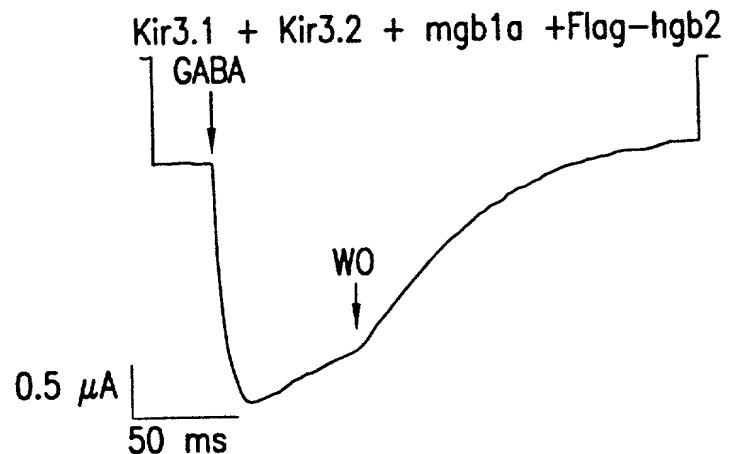
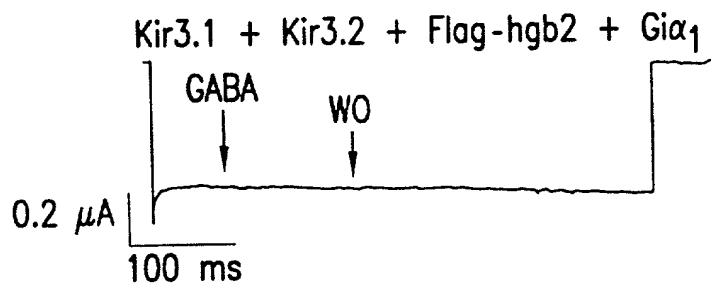
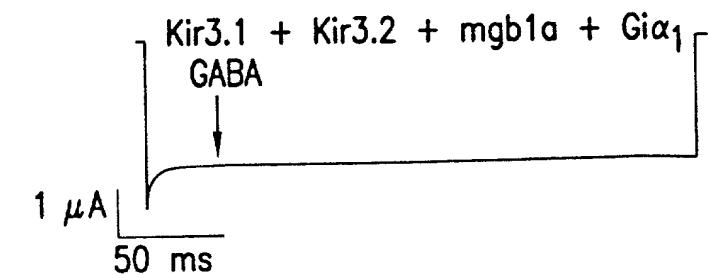


FIG. 13B

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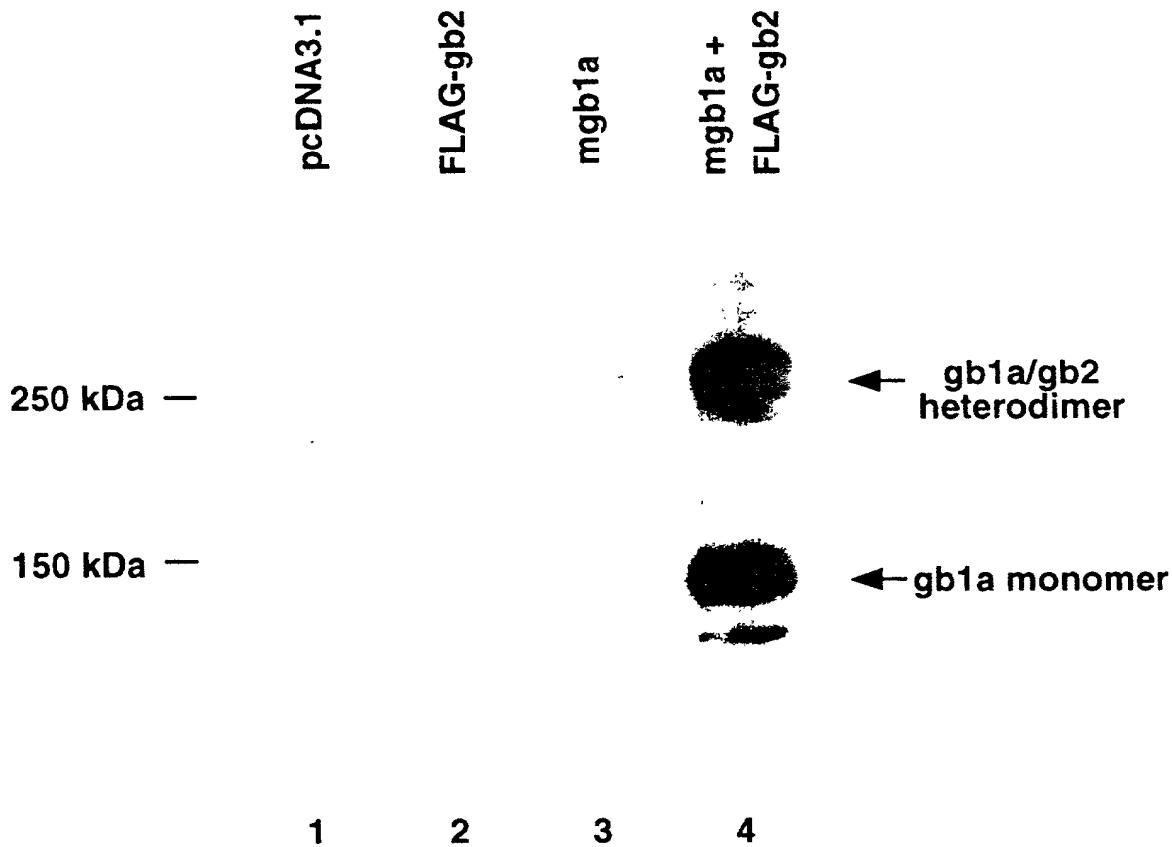


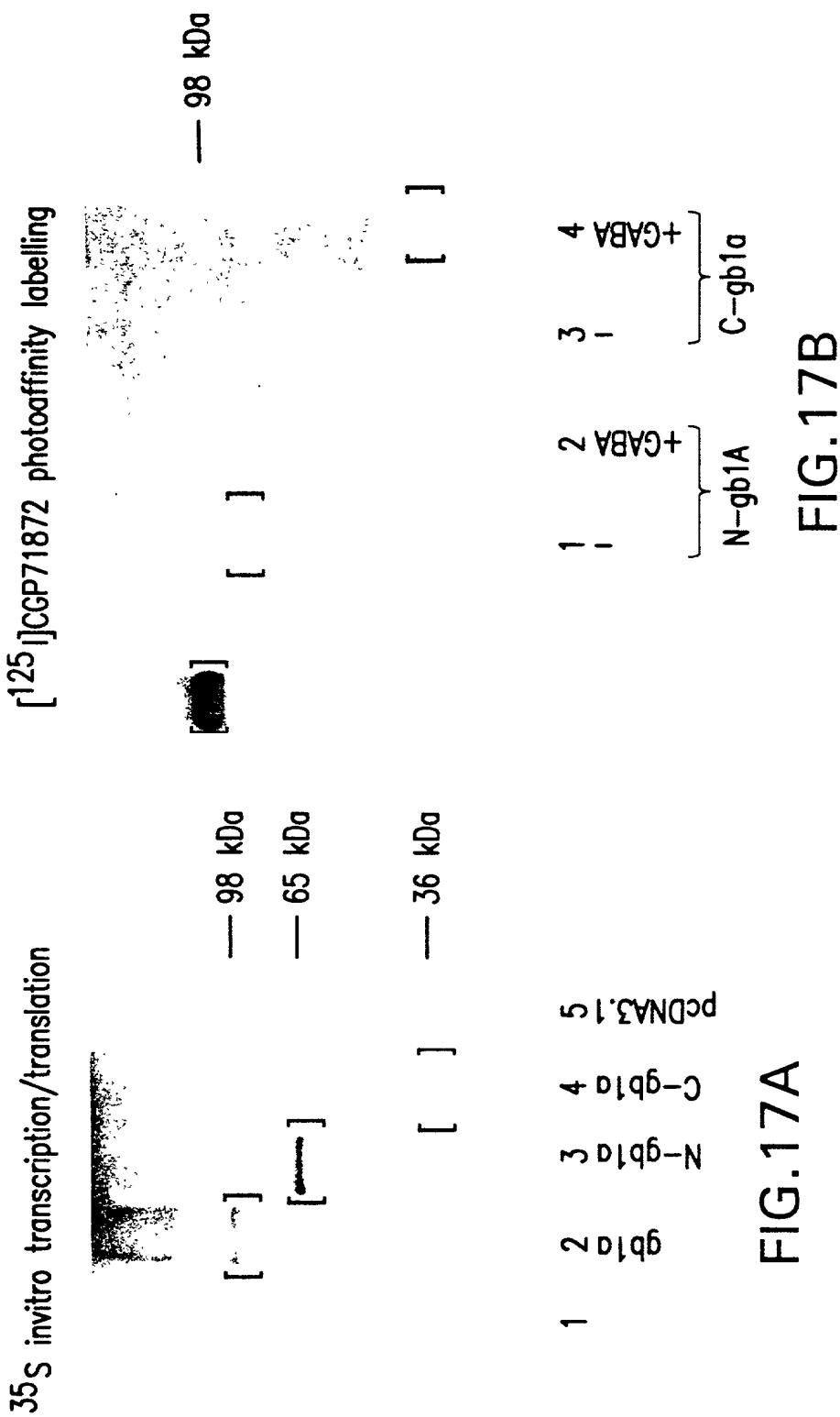
FIG. 14

1 atgctgctgc tgctgcttct gcttctcttc ctccgcccccc tgggcgtgg cggggctcag  
 61 accccccaaacg tcacctcgga aggttgcacag attatacatac cgcctggga aggtggcata  
 121 aggtaccgtg gcttgcattcg cgaccaggtg aaggccatca atttcctgccc tgtggactat  
 181 gagattgaat atgtgtgccg gggcgaacgc gaggtgggtgg ggcggcaagggt ggcgaagtgc  
 241 ctggccaacg gctcctggac ggatatggac acacccagtc gctgtgtccg aatctgtcc  
 301 aagtcttatt tgaccctgga aatgggaag gttttcctga cgggtggggaa cctccagct  
 361 ctggatggag cccgggtggaa tttccatgt gaccctgact tccatctgggt gggcagctcc  
 421 cggagcatct gtagtcaggg ccagtggagc accccccaaagc cccactgcca ggtgaatcga  
 481 acgcccacact cagaacggcg tgcagttatac atcggggcgc tgtttccat gggcggggc  
 541 tggccggggg gccaggcctg ccagcctggt gtggagatgg cgctggagga cgtaaacagc  
 601 cgcagagaca tcctgcccga ctacgagctc aagcttatcc accacgacag caagtgcac  
 661 ccagggcaag ccaccaagaat cttgtatgaa ctacttaca acgacccat caagatcatc  
 721 ctcatgcccc gctgcagctc tgtgtccaca ctggtagccg aggctgccc gatgtggAAC  
 781 cttattgtgc tctcatatgg ctccagctca ccagcctgtt caaaccgaca gcggtttcca  
 841 acgttctttc ggacacatcc atccggccaca ctccacaatcc ccacccgggt gaaactcttc  
 901 gaaaagtggg gctggaaagaa gattgccacc atccagcaga ctaccgaggt cttcacctca  
 961 acactggatg acctggagga gcgagtgaaa gaggctgggaa ttgagatcac tttcgacag  
 1021 agtttcttct cagatccagc tgtgcctgtt aaaaacctga agcgtcaaga tgctcgaatc  
 1081 atcgtgggac ttttctatga gaccgaagcc cgaaaagttt ttgtggaggt ctataaggaa  
 1141 cggctctttg ggaagaagta tgtctgggtt ctcatcggtt ggtatgtca caactggttc  
 1201 aaaacctatg acccgtaat caattgtaca gttagaagaga tgactgaggc ggtggaggc  
 1261 catatcacca cggagattgt catgctgaac cctggcaaca cccgaagcat ttccaaatcg  
 1321 acatcacagg aatttggaa gaaactaacc aagcggctga aaagacaccc tgaggagact  
 1381 ggaggcttcc aggaggcacc actggcctat gatgttattt gggccttggc tttggccttgc  
 1441 aacaagacct ctggaggagg tggccgttca ggagtgcgcc tggaggactt taactacaac  
 1501 aaccagacca ttacagacca atctaccgg gccatgaact cctccctt tgagggtgtt  
 1561 tctggccacg tggctttga tgccagcggc tccggatgg catggacgct tatcggcag  
 1621 ctacagggcg gcagctacaa gaagatcggc tactacgaca gcaccaagga tgatcttcc  
 1681 tggtccaaaa cagacaagtg gatcggaggg tctcccccag ccgaccagac cttggcatac  
 1741 aagacattcc gtttctgtc acagaaaactc tttatctccg tctcagttct ctccagcctg  
 1801 ggcattgttc ttgtgttgt ctgtctgtcc ttaacatct acaactccca cgctcggttat  
 1861 atccagaatt cccagccaa cctgaacaat ctgactgctg tggctgctc actggcactg  
 1921 gctgtgtct tccctctcg gctggatggt taccacatag ggagaagcca gttcccgaaa  
 1981 gtcgtccagg cccgcctttg gctctggc ttggcttta gtctggctca tggctctatg  
 2041 ttcaccaaga tctgtgggtt ccacacagtc ttacacgaa aggaggagaa gaaggagtg  
 2101 aggaagaccc tagacccctg gaaactctat gccactgtgg gcctgctgtt gggcatggat  
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 2281 agctccaaga agatgaatac gtggcttggc attttctatg gttacaaggg gctgtgtcg  
 2341 ctgctggaa tcttcttgc ttacgaaacc aagagcgtgtt ccactgaaaa gatcaatgac  
 2401 cacagggcccg tggcatggc tatctacaat gtcgcggcc tgcgtctcat cactgtccct  
 2461 gtgaccatga tccttccatcg tcagcaggac gcagcccttgc ctttgcctc tctggccatc  
 2521 gtgttctttt cctacatcac tctgggtgtt ctcttgc ccaagatgcg caggctgatc  
 2581 acccgaggagg aatggcagtc tgaaacgcag gacaccatga aaacaggatc atccaccaac  
 2641 aacaacgagg aagagaagtc ccgactgttg gagaaggaaa accgagaact ggaaaagatc  
 2701 atcgctgaga aagaggagcg cgtctgtaa ctgcgcctc agctccagtc tcggcagcaa  
 2761 ctccgctcac ggcgccaccc cccaaacaccc ccagatccct ctggggcct tcccaggggaa  
 2821 ccctctgagc cccctgaccg gcttagctgt gatgggagtc gactacattt gctttacaag  
 2881 tga

MLLLLLLFLRPLGAGGAQTPNVTSEGCIIHPPWEGGIRYRGLIRDQVKAINFLPVDY  
EIEYVCRGEREVVGPVKRCLANGSWTMDTPSRCVRICSKSYLTLENGKVFLTGGDLPA  
LDGARVDFRCDPDFHLVGSSRSICSGQWSTPKPHCQVNRTPHSERRAVYIGALFPMGG  
WPGGQACQPAVEMALEDVNSRRDILPDYELKLIHHDSKCDPGQATKLYELLYNDPIKII  
LMPGCSSVSTLVAEAARMWNLIVLSYGSSSPALSNRQRFPTFFRTHPSATLHNPTRVKLF  
EKWGKKIATIQQTTEVFTSTLDDLEERVKEAGIEITFRQSFFSDPAVPVKNLKRQDARI  
IVGLFYETEARVFCEVYKERLFGKKYVWFLIGWYADNWFKTYDPSINCTVEEMTEAVEG  
HITTEIVMLNPANTRSISNMTSQEFVEKLTKRLKRHPEETGGFQEAPLAYDAIWALAL  
NKTSGGGGRSGVRLEDNYNNQTIDQIYRAMNSSFEGVSGHVVFDASGSRMAWTLIEQ  
LQGGSYKKIGYYDSTKDDLSWSKTDKWIGGSPPADQTLVIKTFRFLSQKLFISVSVLSSL  
GIVLAVVCLSFNIYNHARYIQNSQPNLNNLTAVGCSLALAVVFPLGLDGYHIGRSQFPF  
VCOARLWLLGLGFSLGYSMFTKIWWVHTVFTKKEEKKEWRKTLEPWKLYATVGLLVGMD  
VLTLAIWQIVDPLHRTIETFAKEEPKEDIDVSILPQLEHCSSKKMNTWLGIIFYGYKGLLL  
LLGIFLAYETKSVSTEKINDHRAVGMAIYNVAVLCLITAPVTMILSSQQDAAFASLAI  
VFSSYITLVLVLPVKMRLITRGEWQSETQDTMKTGSSTNNNEEKSRLLEKENRELEKI  
IAEKEERVSELRHQLQRQQLRSRRHPPTPPDPSGGLPRGPSEPPDRLSCDGSRVHLLYK

FIG.16

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MLLLLLLAPLFLRPPGAGGAHTPNATSEGQIIHPPWEGGIRYRGLTRDQVKAINFLPV  
DYEIEYVCRGEREVVGPKVRKCLANGSWTMDTPSRCVRICS  
KSYLTLENGKVFTGGDLPALDGARADFRCDPDFHLVGSSRSICSQQWST  
PKPHCQVNRTPHSERRAVYIGALFPMSGGWPGQACQPAVEMALEDVNS  
RRDILPDYELKLIHHDSKCDPGQATKLYELLYNDPIKIIILMPGCSSVSTLV  
AEAARMWNLIVLSYGSSSPALSNRQRFPTFRTHPSATLHNPTRVKLFEKW  
GWKKIATIQQTTEVFTSTLDDLEERVKEAGIEITFRQSFFSDPAVPVKNLKRQ  
DARIIVGLFYETEARKVFCEVYKERLFGKKYVWFLIGWYADNWFKIYDPS  
INCTVDEMTEAVEGHITTEIVMLNPANTRSISNMTSQEFVEKLTKRLKRHPE  
ETGGFQEAPLAYDAIWALALALNKTGGGRSGVRLEDFNYYNQITDQI  
YRAMNSSFEGVSGHVVFADASGRMAWTLIEQLQGGSYKKIGYYDSTKDD  
LSWSKTDKWIGGSPPADQTLVIKTFRFLSQKLFIISVSVLSSLGIVLAVVCLSF  
NIYNSHVRYIQNSQPNLNNLAVGCLALAAVPLGLDGYHIGRNQFPV  
CQARLWLLGLGFSLGYSMFTKIKWWHTVFTKKEEKKEWRKTLEPWKLY  
ATVGLLVGMDVTLAIWQIVDPLHRTIETFAKEEPKEDIDVSILPQLEHCSS  
RKMNTWLGIFYGYKGLLLLGIFLAYETKSVSTEKINDHRAVGMAIYNVA  
VLCLITAPVTMILSSQQDAAFAFASLAIVFSSYITLVVLFVPKMRRLITRGE  
WQSEAQDTMKTGSSTNNNEEKSRLLEKENRELEKIIAEKEERVSELRHQLQ  
SRQQLRSRRHPPPTPPEPSGGLPRGPPEPPDRLSCDGSRVHLLYK

FIG.18A

1 atgttgcgtc tgctgctact ggccyccactc ttccctccgccc ccccccggcgc gggccggggc  
61 cataccccca acgcccaccc tcgac agaagggtgc cagatcatac accccgcctg ggaaggggc  
121 atcagggtacc ggggcctgac tcgggaccag gtgaaggcta tcaacttcctt gccagtggac  
181 tatgagatttgc agtatgtgtc cgggggggag cgccgagggtgg tggggcccaa ggtccgcaag  
241 tgcctggcca acggccctg gacagatatg gacacacccca gccgctgtgt ccgaatctgc  
301 tccaagtctt atttgaccctt gaaaaatggg aaggtttcc tgacgggtgg ggaccccca  
361 gctctggacg gagcccccggc ggatttccgg tgcgaccctt acttccatct ggtggcggc  
421 tcccggagca tctgtgtca gggccagttgg agcacccttcc agccccactg ccaggtgaat  
481 cgaacgcac actcagaacg ggcgcgcgtg tacatgggg cactgtttcc catgagcggg  
541 ggctggccag gggccaggc ctgcccggcc gccgggtggaga tggcgctgga ggacgtgaat  
601 agccgcaggg acatccgtcc ggactatgag ctcaagctca tccaccacga cagcaagtgt  
661 gatccaggcc aagccaccaa gtacctatata gactgtctt acaacgaccc tatcaagatc  
721 atccttatgc ctggctgcag ctctgtctcc acgctgggtgg ctgaggctgc taggatgtgg  
781 aacctcatttgc tgcttcctt tggctccagc tcaccagccc tgcgttaccccg gcagcggttcc  
841 cccactttct tccgaacgc cccatcagcc acactccaca acccttaccccg cgtggaaactc  
901 ttggaaaatg gggctggaa gaagattgtt accatccagc agaccactga ggttttcaact  
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1081 atcatcgtgg gacttttcta tgagactgaa gcccggaaag tttttgtga ggttacaag  
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1321 atgacatccc aggaattttgtt ggagaaaacta accaagcgac taaaagaca ccctgaggag  
1381 acaggaggct tccaggaggc accgcgtggcc tatgtatgcca tctggccctt ggcactggcc  
1441 ctgaacaaga catctggagg aggcggccgt tctgggtgtc gcctggagga cttcaactac  
1501 aacaaccaga ccattaccga ccaaatttctac cggcaatga acttttcgtc ctttgggggt  
1561 gtctctggcc atgtgggttt tgcgttgc accgcgtggcc tggcatggac gctttatcgag  
1621 cagtttcagg gtggcagacta caagaagatt ggctactatg acagcacccaa ggtatgtctt  
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1861 tatatccaga actcacagcc caacctgaac aacctgactg ctgtgggtgt ctcaactggc  
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1981 ttcgtctgcc agggccgcctt ctggctcctt ggcctggct ttagtctggg ctacgggttcc  
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2281 tgcagctcca ggaagatgaa tacatggctt ggcattttctt atggttacaa gggctgtgt  
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2461 cctgttccca tgattctgtc cagccagcag gatgcagccctt tgccttgc ctcttgc  
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2581 atcaccggag gggaaatggca gtcggaggcg caggacacca tgaagacagg gtcacatcgacc  
2641 aacaacaacg aggaggagaa gtcccggtt gttggagaagg agaaccgtga actggaaaag  
2701 atcattgttgc agaaagagga gctgttgc ttttttttttcaacttca gtcgttgc  
2761 cagctccgtt cccggccca cccaccgaca ccccccagaac cctctggggg cctggccagg  
2821 ggaccccccgtt agccccccgtt ccggcttagc tgcgtatggg gtcgttgc tttgttttat  
2881 aagtga

FIG. 18B

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1 atgctgctgc tgctgctggc gccactcttc ctccgcccc cgggcgcggg cggggcgcag  
 61 acccccaacg ccacccatcaga aggttgcacg atcatatacc cgcctggaa agggggcatc  
 121 aggttaccggg gcctgactcg ggaccaggtg aaggctatca acttcctgaa agtgactat  
 181 gagatttgggt atgtgtcccg gggggagcgc gaggtgggtg gccccaaagggt ccgcaagtgc  
 241 ctggccaacg gtcctggac agatatggac acaccagcc gctgtgtccg aatctgctcc  
 301 aagtcttatt tgaccctggaa aaatgggaag gttttccatc cgggtggggaa cctcccaagct  
 361 ctggacggag cccgggtggaa tttccgggtg gaccggact tccatctggt gggcagctcc  
 421 cggagcatct gtatgtcccg ccagtggagc acccccaagc cccactgcca ggtgaatcga  
 481 acgcccacact cagaacggcg cgcagttac atcggggcac tttttccat gggcggggc  
 541 tggccagggg gcccaggctg ccagcccgcg gtggagatgg cgctggagga cgtaatagc  
 601 cgcaggggaca tcctggcggaa ctatgagctc aagctcatcc accacgacag caagtgtat  
 661 ccaggccaag ccaccaagta ccttatatgag ctgctctaca acgaccctat caagatcatc  
 721 cttatgcctg gtcagctc tgcctccacg ctggggctg aggctgctg gatgtggaaac  
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 841 actttcttcc gaacgcaccc atcagccaca ctccacaacc ctaccgcgt gaaactcttt  
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 1081 atcgtgggac ttttctatga gactgaagcc cggaaagttt tttgtgaggt gtacaaggag  
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 1201 aagatctacg acccttctat caactgcaca gtggatgaga tgactgaggc ggtggaggc  
 1261 cacatcacaa ctggaggattgt catgctgaat cctgccaata cccgcagcat ttccaaatcg  
 1321 acatcccgagg aatttggaa gaaactaacc aagcactga aaagacaccc tgaggagaca  
 1381 ggaggcttcc aggaggcacc gctggcctat gatgccatct gggccttggc actggccctg  
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 1621 cctcagggtg gcagttacaa gaagattggc tactatgaca gcaccaagga tggatcttcc  
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 1741 aagacattcc gcttctgtc acagaaactc tttatctccg ttcctgttct ctccagctg  
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 1861 atccagaact cacagccaa cctgaacaac ctgactgtc tggctgtc actggcttta  
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 1981 gtcgtccagg cncgcctcg gctcctggc ctggcctta gtctggctt cgggtccatg  
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 2221 gccaaggagg aacctaagga agatattgtac gtctctattt tggccagct ggacattgc  
 2281 agctccagga agatgaataac atggcttgc attttctatg ttacaaggg gctgctgtc  
 2341 ctgtggggaa tcttccttgc ttatgttgc aaggtgtgtt ccactgagaa gatcaatgt  
 2401 caccgggctg tggcatggc tatctacaat gtggcgtcc tgcgtccat cactgtcc  
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 2701 attgttgcaga aagaggaggcgt tgcgtccatc aactccagtc tcggcagcag  
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 2821 ccccccgtggc ccccccgtggc gcttagtgc tatctacaat gtggcgtcc tgcgtccat  
 2881 tgagggttggg gttggggaggc acaggccatgtt gggggggggg aaaggggaggg gggagg  
 2941 ggggacttcgtc gaaggcagggg gttccatcc ccaagctggaa agaacatgtc atccaatctc  
 3001 atctcttgcata aatacatgtc cccctgtggat ttctgggttgc atttgggttgc ttcataatctc  
 3061 tgggaaacag accttttttctt ctcttactgc ttcatgtat tttgtatcacttccat

FIG.19A

3121 tttagttcgtaacctggcttg aagctgctca ctgctcacac gctgcctcct cagcagccct  
3181 actgcacatctt tctcttccca tgcaacacccc tcttcttagtt accacggcaa cccctgcagc  
3241 tcctctgcct ttgtgctctg ttccctgtcca gcaggggtct cccaaacaagt gctcttcca  
3301 ccccaaagggc gcctctccctt ttctccactg tcataatctc ttccatctt acttgccctt  
3361 ctataactttc tcacatgtgg ctccccctga attttgcttc ctttgggagc tcattcttt  
3421 cgccaaaggct cacatgctcc ttgcctctgc tctgtgcact cacgctcagc acacatgcat  
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3541 tgctttcttc atgttcagtc acatgtgctc tcgggtgccc tgcatcaca gctacgtgt  
3601 cccctctcat ggtcatgggt ctgcccattga gcgtgtttgg gtaggcatgt gcaatttgc  
3661 tagcatgctg agtcatgtct ttccattttg cacacgtcca tgtttatcca tgtactttcc  
3721 ctgtgtaccc tccatgtacc ttgtgtactt tcttccctta aatcatggta ttcttctgac  
3781 agagccatat gtacccttacc ctgcacatttgc ttatgcactt ttccccattt catgtttgg  
3841 ggggccccatcc acaccctctc ttgtcacag aatctccatt tctgctcaga ttccccccat  
3901 ctccattgca ttcatgtact accctcagtc tacactcaca atcatcttct cccaaagactg  
3961 ctcccttttgc ttgtgtttt ttgtgttttttggg aattaaggaa aaataagtgg gggcaggttt  
4021 ggagagctgc ttccagtggta tagttgatga gaatcctgac caaaggaagg cacccttgac  
4081 tttttggata gacagatggta cctatgggtt gggaggtgggt gtcccttca cactgtgg  
4141 tctcttgggg aaggatctcc ccgaatctca ataaaccagt gaacagtgtg actcgaaaa  
4201 aaaaaaaaaaaaaaaa aaaaaaaaaaaaaaaa

FIG.19B

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## PROXIMAL TO HSN-1. FCMD, DYS LOCI ON CHROMOSOME 9

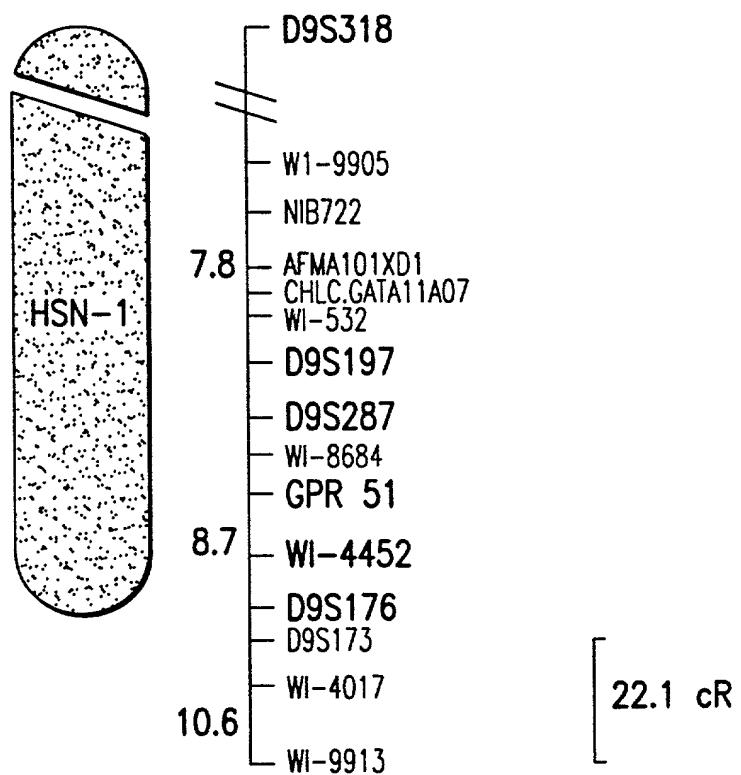


FIG. 20

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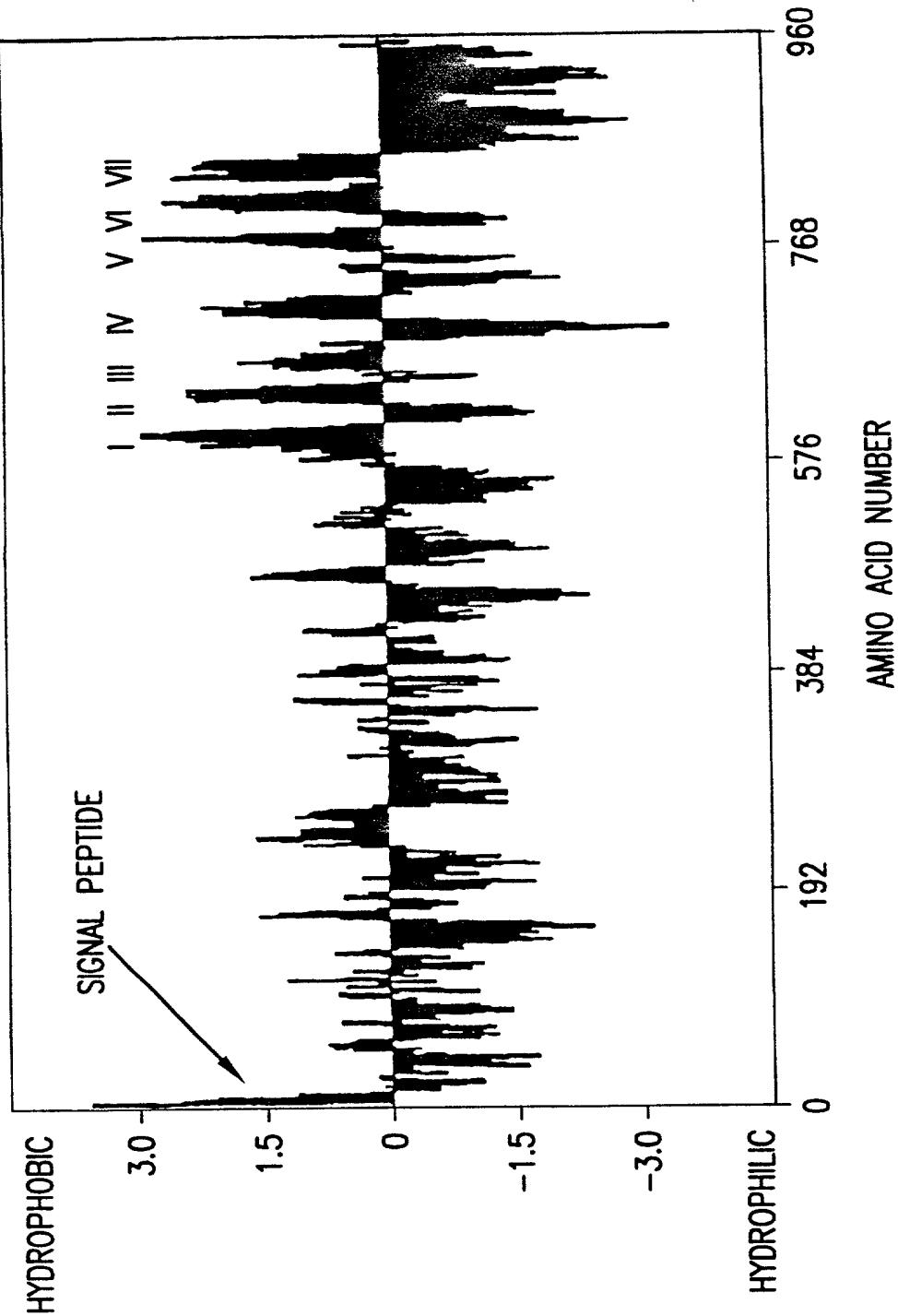


FIG. 21

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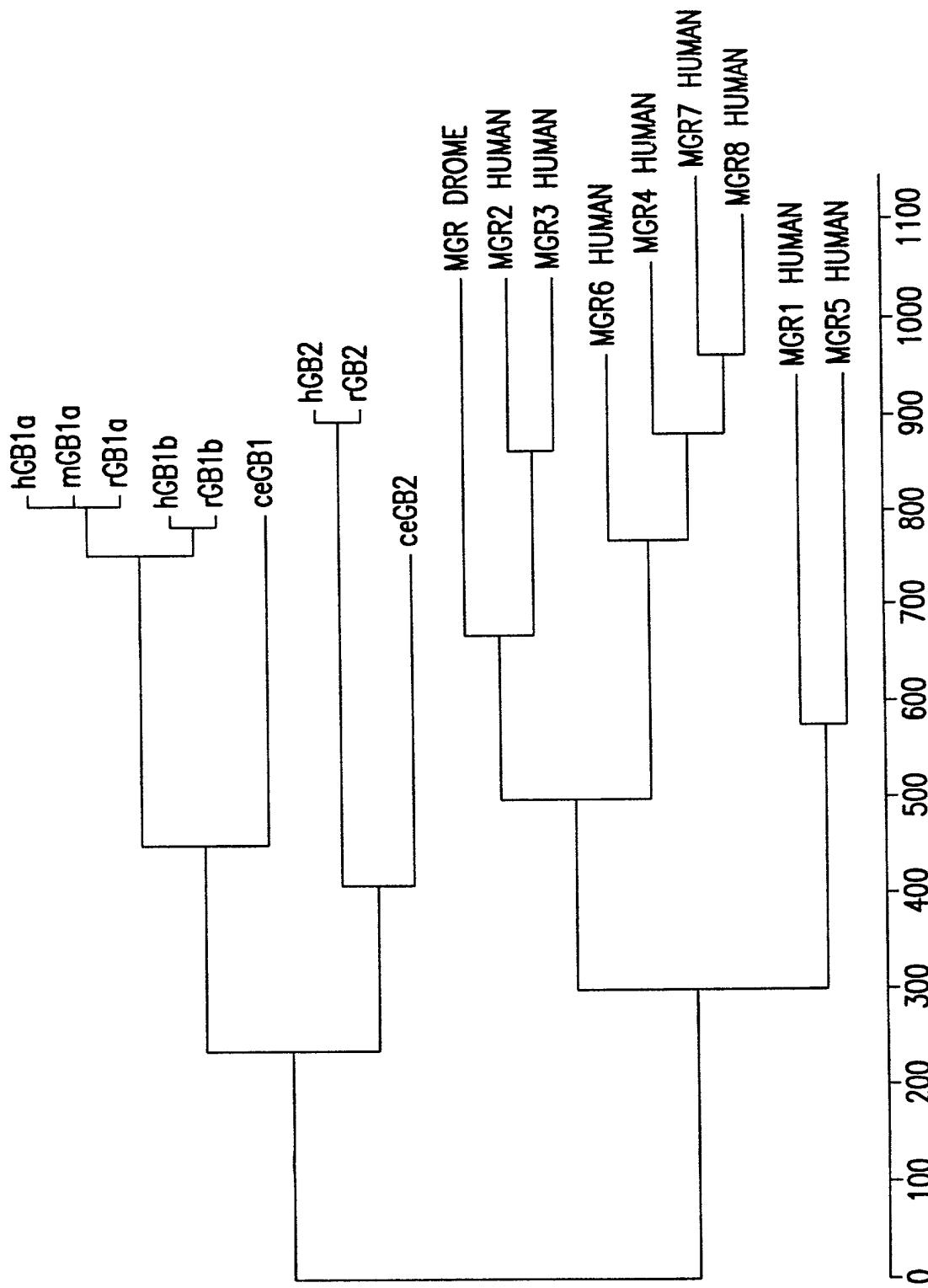


FIG. 22

COILED-COIL DOMAIN IN C-TERMINUS OF qb1a AND HG20  
MEDIATING HETERO-DIMERIZATION

qb1 ... WQSEA. QDTMKTGSSSTNNNEEK... SRLEK. ENRELEK IIAEKEERVSELRH QLSRQQLRSRRHPP  
hg20 QNRRRFQTQNQKKEDSKTSTS VTSWQASTSRLEGLOSENHRRLMK I TELDKDLEEVTMQLQDTEPKTTYIKQN

FIG.23

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Human GABA-B1αR	MLLMLLAPLFLRPPGAGGAQTTPNATSEGCGI IHPPIWEGG IRYRGL TRDQVKA INFILPVDEYE IYVYRCGEREVVGPVKVRKCLANGSWTMDTILSRCVRICKSYLT
C. elegans GABA-B1	-----
C. elegans GABA-B2	-----
Human GABA-B2	-MASPRSSGQPGPPPPPPP-----
	PA-----
10 20 30 40 50 60 70 80 90 100	
110 120 130 140 150 160 170 180 190 200 210 220	
230 240 250 260 270 280 290 300 310 320 330 340	
350 360 370 380 390 400 410 420 430 440	
450 460 470 480 490 500 510 520 530 540 550 560	

ENGKVFLIGGDLPA[D]GARD[FRCDDPFHLV[GSSRSI[SQG]QWSTPKPKHQVNRTPHSERRAVYIGALFPMSGGMPGGQACQPAVEMAE[DVN]SR[D]DLPY[E]KLH[D]S[D]Q[D]P[E]GQ  
 AT[KY]YELYD[D]P[KI]IMPG-[CS]S[SI]VAE[AARM]IIVSYG[G]SS[SP]AISNRQEP[FE]RTHPSA[T]LH[N]PTRKVLFEKMGW[K]KIAITIQQTTEVFTS[D]DLE[ER]VKEAG[E]IT[FR]  
 AMQQLYDFYKPF[KI]MLTG-[CS]PMTVIAEAA[P]V[K]WLSYG[G]SS[SP]AISNRQEP[FE]RTHPSA[N]QNPTRI[H]MEF[KW]KRF[FT]LMSVEEVFTS[D]DLE[ER]KK[G]KVD-R  
 GKA[F]DLSASRPRPVAIIGGQCTEENP[T]AMAKYQWQIVQLSMAETHAMNGQLQFTTFFRWR[G]SRNITMAK[G]FVNF[G]WKR[G]VTF[K]N[D]O-----  
 GLKA[F]DLSASRPRPVAIIGGQCTEENP[T]AMAKYQWQIVQLSMAETHAMNGQLQFTTFFRWR[G]SRNITMAK[G]FVNF[G]WKR[G]VTF[K]N[D]O-----  
 QSFSDPWPVKL[K]QDARITVGLFY[E]TEARKYFCEVYKEF[D]KYYWFL[G]WYADNWKIYDP--S[NC]VDEMTEAECHITTEI[ML]NPAN-----TR[SS]VIT[TS]QEE[ME]K  
 QSFSDPDTAMKLTQDARITVGLFY[E]TEARKYFCEVYKEF[D]KYYWFL[G]WYADNWKIYDP--EEH[NC]TAEQMTAAEMH[T]TE[SM]LSRN-----PA[SE]MT[G]QFQR  
 -----PRYAIYRC[D]VRIITVWDVDEEAMAM[DAG]YHRGMYDNMWT[PQYHSDR]LQ-----THDNC[TE]VEEMR[AA]KNHFST[E]FALTRDWT[K]IVGNMSPV[VT]LN[Q]FQR  
 EFSNDPCTSVKK[G]NDVRIILQfD[OM]AAKfN[OC]AYEENM[G]SKYQW]IPGWWYEP[SI]WEDQVHTEANSSRC[R]KRNLLAAMEG[Y]GDEEPLSSKQ---IK[TS]OKTPC[O]YERE

FIG. 24A

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570 580 590 TMS-1 610 620 630 TMS-2 650 660 TMS-3  
 TD[KW]Q-SP[AD]QTLV[KE]KTER-FL[SQ]Q[F]ISV[S]LSS[G]M[AV]C[SE]N[YN]SH[VR]Y[Q]N[SOP]N[NN]TAV[G]CS[L]A[A]V[F]P[L]Q[D]G-[YH]IGRNQFFV[C]QAR[L]W[L]Q[G]FISLG  
 KE[QW]LNG[KP]P[D]-S[V]K[T]EN-Sy[S]D[F]I[F]S[ST]I[Q]YF[S]Q[F]AL[L]H[V]S[TF]LH[KN]I[IF]Q[SO]P[C]N[N]L[IG]CS[CL]F[SL]F[LI]G[P]SDD[IS]SES[EL]F[LI]G[F]F[FA]  
 IDST[K]RWS[P]P[D]-S[V]T[ERRE]H[IS][FL]A[S]L[AI]G[IF]L[AL]I[F]L[IN]Y[R]N[R]F[IK]M[SS]P[N]N[NI]IAGS[CT]F[AS]V[IM]G[DT]-RIVSPD[F]W[Q]Y[T]K[T]W[TC]G[CF]S  
 DT[IR]FQ[G]SE[P]P[D]Q[K]T[IL]E[Q]R-K[LS]P[YL]S[IS]L[AT]G[MM]A[S]E[L]F[N]K[R]Q[K]L[IK]M[SS]P[Y]M[N]L[LG]GML[S]Y[A]S[I]F[L]G[L]D--SFV[SEE]K[TE]T[OT]V[R]W[L]T[V]G[Y]TA  
 680 690 700 710 720 TMS-4 730 740 750 760 TMS-5 790  
 YGSM[F]T[K]I[M]W[V]T[V]F[T]KKE[K]KE[W]K[T]E[P]W[Q]L[Y]A[T]G[L]Y[G]M[D]V[L]T[A]I[Q]M[D]P[L]H[P]T[E]T[KE]E[P]K[E]P[D]V[S]L[B]Q[L]E[H]C[S]R[K]M[N]T[L]G[J]F[Y]G[Y]K[C]L[L]L[G]F[J]L[Y]E[C]T[K]SV  
 YGSM[F]A[K]M[M]W[V]R[M]G[A]T[N]Q[Q]L[A]S[R]Q[P]I[S]S[F]Y[V]V[A]A[T]A[V]F[V]C[V]W[L]I[D]P[L]H[E]Q[K]P[L]F[A]D[S]-E[D]W[M]P[M]Q[G]Q[S]N[Q]Q[E]W[M]G[C]I[M]G[F]K[C]L[L]L[G]F[J]S[Y]E[T]RNL  
 F[G]A[M]E[S]K[T]W[R]V[S]I[F]T[N]--I[R]D[R]Q[A]T[K]D[S]K[F]I[G]L[F]F[D]Q[M]V[T]M[A]F[V]S[P]F[S]Y[V]E[Q]F[K]L[I]F[S]A[R]F[N]V[I]P[E]V[K]N[S]S[G]C[V]F[G]A[V]L[Y]A[M]G[C]M[M]I[G]C[F]L[A]W[I]T[R]V  
 F[G]A[M]E[A]K[T]W[R]V[H]A[F]K[N]--V[K]M[K]K[I]K[D]Q[K]L[V]V[G]M[I]D[G]I[OM]Q[A]V[D]P[L]R[R]T[V]K[S]M[E]P[D]P[A]C[D]O[L]S[I]R[P]L[E]H[C]E[N]T[MT]IWL[G]I[V]A[Y]K[G]L[M]F[G]C[F]L[A]W[E]T[R]V  
 800 810 → TMS-6 830 TMS-7 850 860 870 880 890  
 STE[K]IND[H]R[A]NG[MA]I[Y]N[V]A[V]C[L]I[A]P[Y]T[M]I[L]S-Q[D]A[A]F[A]F[A]S[A]J-[V]F[S]S[Y]J[L]V[V]F[V]P[M]Y[R]L[T]R[G]E[W]Q[S]--E[Q]D[T]M[K]T[G]S[S]T[N]N[EE]E[S]R[L]E[K]E[N]R  
 KLR[F]IND[S]R[F]V[G]L[A]I[Y]N[V]A[V]M[T]M[T]A[P]W[V]T[J]I[H]G[K]V[D]A[N]F[A]F[I]S[T]S[V]L[I]C[Y]S[V]G[L]I[Y]G[P]D[I]B[H]I[K]V[P]S[A]D--E[I]Q[LN]G[V]G[P]G[V]M[S]K[V]D[Q]--  
 N[P]A[L]NDS[K]YI[G]S[V]Y[C]V[V]S[V]I[G]S[T]S[V]L[Q]E-R[V]N[E]M[F]S[L]A[S]F-F-V[F]S[T]M[L]L[C]L[V]P[V]A[V]F[L]C[C]G[S]--  
 S[P]A[L]NDS[K]YI[G]S[V]Y[N]G[I]C[I]G[A]V[S]F[L]T[D]-Q[P]V[G]C[I]V[A]L[V]--I[R]TNP[DA]ATQNRRFQFTQNQKKEDSKTSTS[V]T[V]NQ[A]S[T]S[R]LEGLOSEN[H]  
 900 910 920 930 940 950 960  
 ELE[K]I[I]A[E]KE[E]V[SE]R[H]Q[L]Q[S]R[Q]Q[R]S[R]R[H]P[P]T[P]E[P]S[G]G[P]R[G]--PPEPPD[R]LSCDGSRVHLLYK--  
 RLRMK[I]TEL[D]K[D]OLE[V]T[M]Q[L]Q[D]TPEK[T]YIKQ[N]H[Q]E[L]N[D]I[L]N[G]N[TEST]D[G]K[A]I[L]K[N]HLDQ[N]P[Q]LQ[N]TTE[P]S[R]T[C]K[D]P[I]E[D]I[N]S[P]E[H]I[Q]R[R]LSLQ[P]L[H]AY[L]P[S]IG[G]V[D]AS  
 CVSPCV[S]PTASPRHRVPPSFRVMV[S]CL

FIG.24B

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FIG. 25D

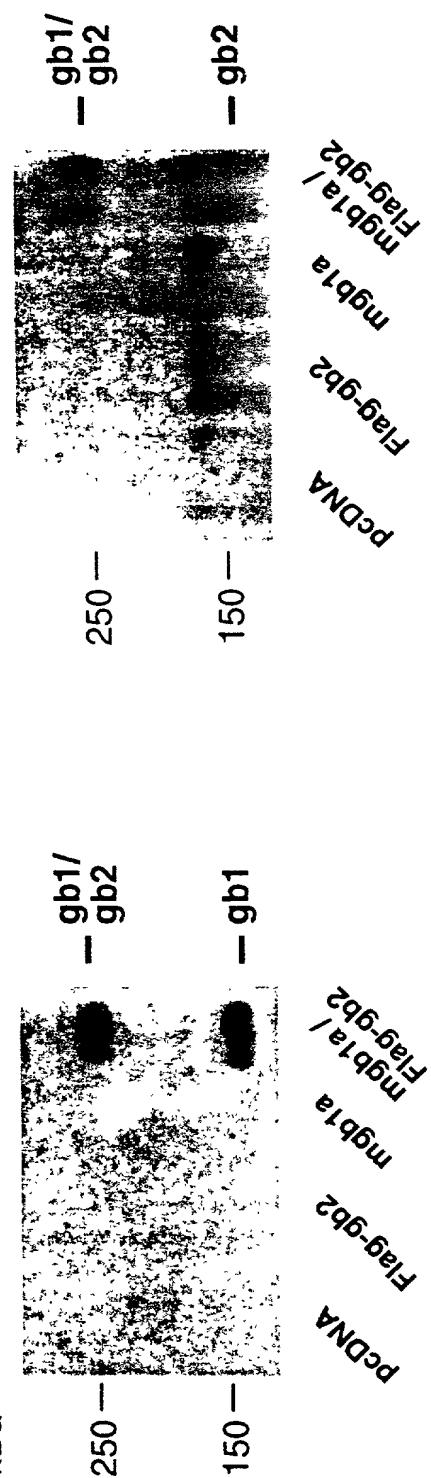


FIG. 25B



FIG. 25A

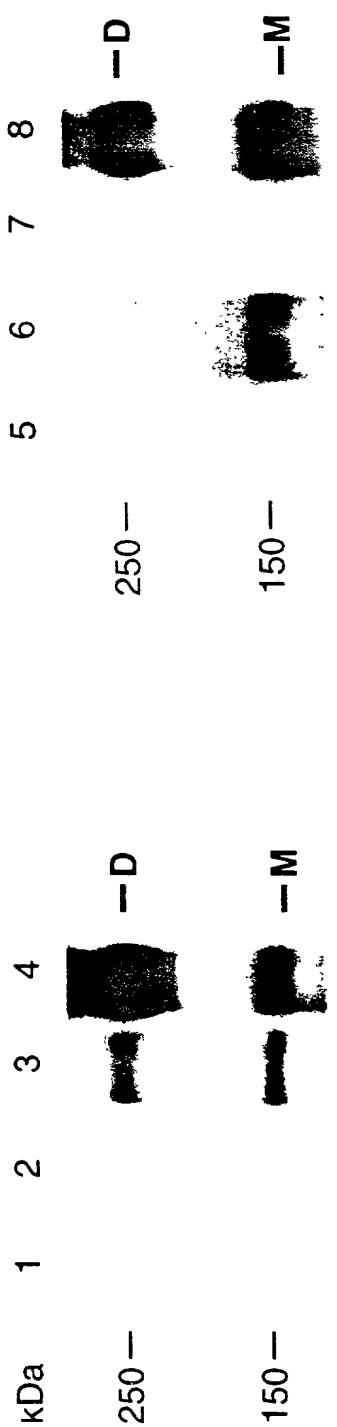


FIG. 25C



FIG. 25D

FIG. 26A-1

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mGABab1a EITFROSSESDPAVPVKN . . . . . KRDARI . . . . . IVCLEYET . . . . . EARKVFCVEYKERLFGVYVWFLIGMYADNMFK . . . . . TYDPSINCTIVEEM . TEAEQGHITTE . . . . . IVMLNP:431  
 hGABab1a EITFROSSESDPAVPVKN . . . . . KRDARI . . . . . IVCLEYET . . . . . EARKVFCVEYKERLFGVYVWFLIGMYADNMFK . . . . . IYDPSINCTVDEM . TEAEQGHITTE . . . . . IVMLNP:432  
 hGABab2 EISDTEFSNODCTSVK . . . . . LGNDVRI . . . . . LGQFDQN . . . . . MAAKVFCCAYEENMVGQ . . . . . QWITPGWYEPSWMEQ . . . . . VHTEANSSRCLRKNL . LAAMEGIVGVD . . . . . FEPLSS:324  
 mGluR1 CHASDKIYSN . . . . . AGERKFSDRILPKLRLERL . . . . . RRLGIVGEFSLIG . . . . . SDGMADRDEVIEGYEVAENGIT . . . . . IKLOSPENRFSDDYFLKLRLDTN:362  
 LivK KAANANWFFDCITAGEQSALL . . . . . ARIKKENIDFV . . . . . GGYPPFEMGQMLRQA . . . . . RSVGLKTOF . . . . . MG . . . . . PEG . . . . . V . . . . . GNASLSNIAQDAAEG . . . . . M.LVTM:271  
 LivBP KRGNAWVEFFDCITAGEQSALL . . . . . ARIKKENIDFV . . . . . GGYHPEMQLRQA . . . . . RAAGLKITOF . . . . . MG . . . . . PEG . . . . . V . . . . . ANVLSNSNIAQSAEG . . . . . L.LVTK:248

mGABab1a ANTRSISSMTSQEFVEKLTKRLKRPE . . . . . ETGGF . . . . . QEARLAYD . . . . . AIVMIALALINK . . . . . TSGCCGRSGVRLED . . . . . NQTIIDQIYRAM . . . . . TSSSFEQVGSQHWM . . . . . FDAQSRSRMA:534  
 hGABab1a ANTRSISSMTSQEFVEKLTKRLKRPE . . . . . ETGGF . . . . . QEARLAYD . . . . . AIVMIALALINK . . . . . TSGCCGRSGVRLED . . . . . NQTIIDQIYRAM . . . . . TSSSFEQVGSQHWM . . . . . FDAQSRSRMA:535  
 hGABab2 KQIKTISGKTPQQYEREYNN . . . . . KRSGV . . . . . GPSKF . . . . . HG . . . . . YAYD . . . . . GIVWIAKTLQRMETLHASSRHQ . . . . . RIQDFNYTDHTLGRILLNAMETIN . . . . . FGVIQOW . . . . . FR . . . . . ANGERMG:424  
 mGluR1 TRNPWMPPEFWQHRFQCRLPGHLLENPKRRICTGNESLEENYQDSKAGFVINAYMAGLQ . . . . . NMHMHALCPGHVGL . CDAMKPID . . . . . GSKLLDFLIIKSSE . . . . . GYSSCEEMWDEKGDAPG:477  
 LIVK PK . . . . . RYD . . . . . QDPANQGIV . . . . . DALKAD . KKDPSGPV . . . . . WITYYAVQSLATALERGSDEPLAL . VKD[KANG] . . . . . ANTVIGPLN . . . . . WDEKGDLKG:351  
 LivBP PK . . . . . NYD . . . . . QVPAKPTIV . . . . . DAIAKAK . KQDPSQAFV . . . . . WITYYAALQSLQAGLNLQ . . . . . SDDPAEI . AKYLKANS . . . . . VDTVMGPLT . . . . . WDEKGDLKG:326

mGABab1a WTL IE . . . . . QLQGGSYK1GYYD . . . . . STKDDLS . WSKTDKWIGGS . . . . . PPAQ . . . . . 575  
 hGABab1a WTL IE . . . . . QLQGGSYK1GYYD . . . . . STKDDLS . WSKTDKWIGGS . . . . . PPAQ . . . . . 575  
 hGABab2 . TIKFT . . . . . QFQDSREVKYCEYN . . . . . AVADTEIINDTIRFQGSE . . . . . PPKDXTIILEQLR . . . . . 475  
 mGluR1 RYDIMNQYTEAMRYDYVHVG . . . . . WHEGVLNIDDYK1QMNKSGWRSVCESPCKGQIKVIRKGEYSCCWICTACKENEYQDEFITCKACDLGWPNNADLTGCEP1PYRY:585  
 LIVK . . . . . FDF . . . . . GMFQ . . . . . WHADGS . . . . . STAK . . . . . 369  
 LivBP . . . . . FEF . . . . . GMFD . . . . . WHANGT . . . . . ATDAK . . . . . 344

FIG.26A-2

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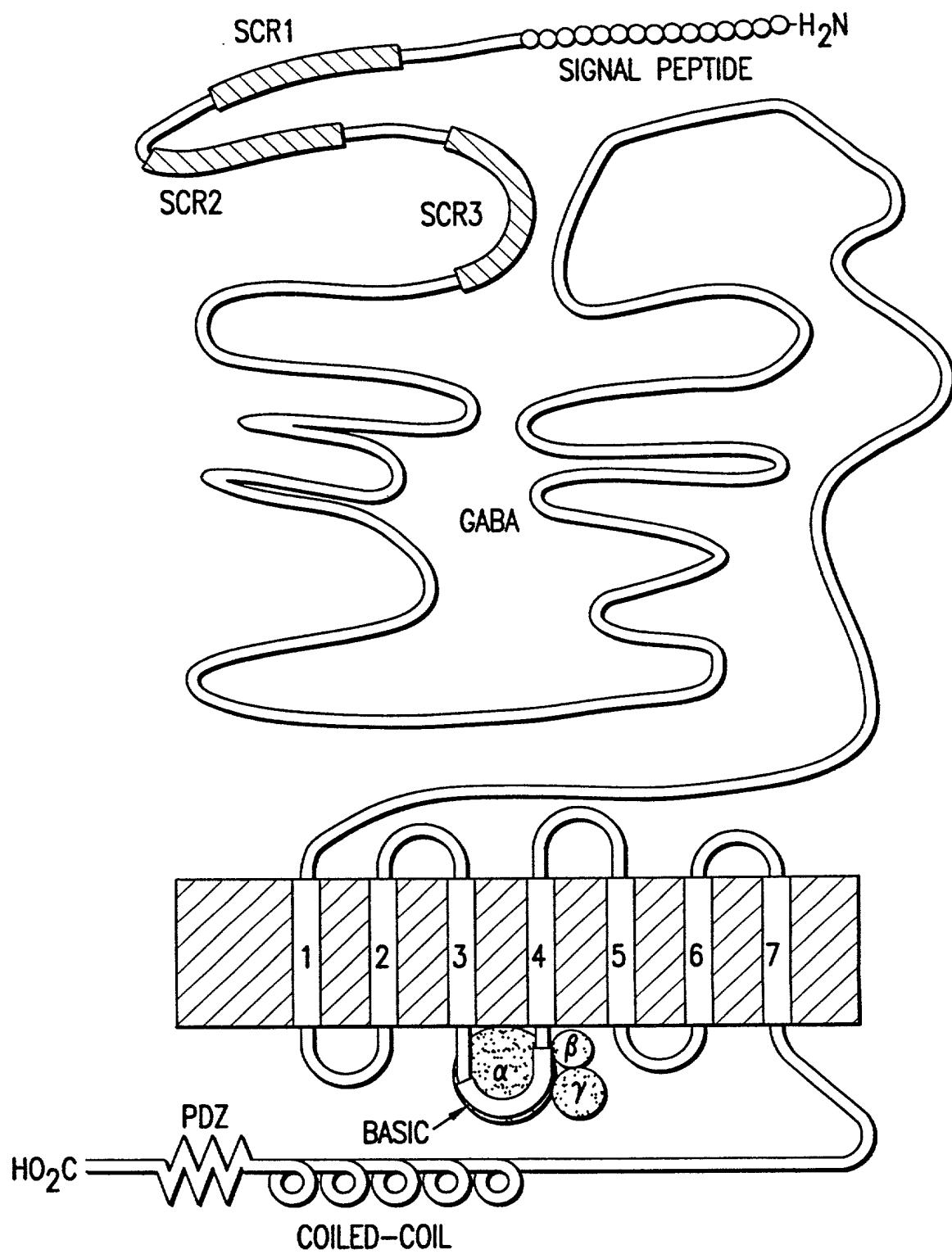


FIG.26B

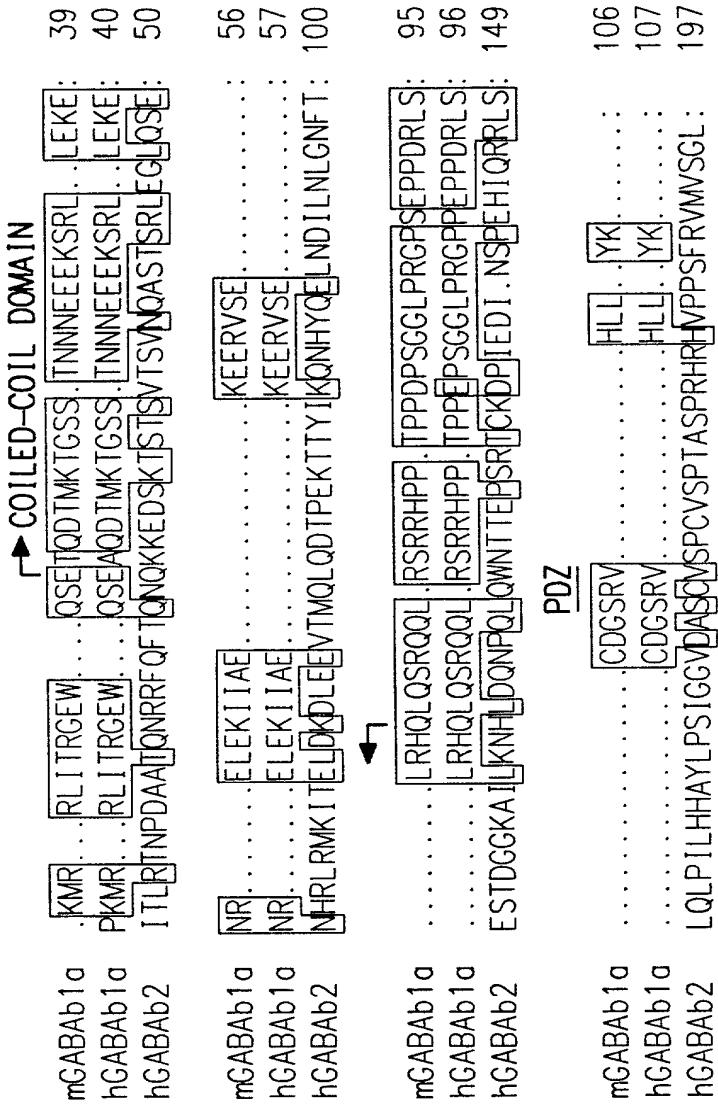


FIG. 27

**DECLARATION AND  
POWER OF ATTORNEY  
FOR UTILITY OR DESIGN  
PATENT APPLICATION  
(37 CFR 1.63)**

Declaration Submitted with Initial Filing

OR

Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	20052YP
First Named Inventor	Liu, et al.
<b>COMPLETE IF KNOWN</b>	
Application Number	09/601,582
Filing Date	
Group Art Unit	
Examiner Name	

**As a below named inventor, I hereby declare that:**

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

NOVEL GABAB RECEPTOR DNA SEQUENCES

*(Title of the Invention)*

the specification of which

is attached hereto

OR

was filed on (MM/DD/YYYY)  as United States Application Number or PCT International

Application Number  and was amended on (MM/DD/YYYY)  (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose to the Patent and Trademark Office all information known to me to be material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Attorney Docket Number	Priority Claimed? YES <input checked="" type="checkbox"/> NO <input type="checkbox"/>
PCT/US99/02361	02/03/1999			<input checked="" type="checkbox"/> <input type="checkbox"/>
				<input type="checkbox"/> <input type="checkbox"/>
				<input type="checkbox"/> <input type="checkbox"/>
				<input type="checkbox"/> <input type="checkbox"/>

Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)	Attorney Docket Number
60/073,767	02/05/1998	20052PV

## DECLARATION AND POWER OF ATTORNEY for Utility or Design Patent Application

I hereby claim the benefit under 35 U.S.C 120 of any United States application(s), or 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose information known to me to be material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application or PCT Parent Application Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number (if applicable)
PCT/US99/02361	02/03/1999	
60/073,767	02/05/98	

Additional U.S. or PCT international application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

As a named inventor, I hereby appoint, respectively and individually, as my attorneys or agents with full power of substitution and revocation, the following registered practitioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Customer Number  →  Place Customer Number  
OR  Bar Code Label here  
 Registered practitioner(s) name/registration number listed

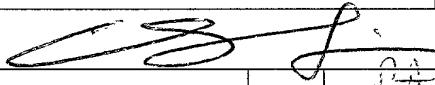
Name	Registration Number	Name	Registration Number
Joseph A. Coppola	38,413	Jack L. Tribble	32,633

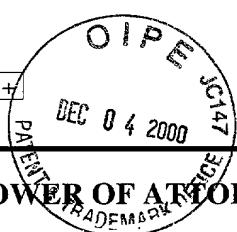
Direct all correspondence to:  Customer Number or Bar Code Label

**000210**

Name	Joseph A. Coppola				
Address	Merck & Co., Inc. - Patent Department				
Address	P.O. Box 2000, RY60-30				
City	Rahway	State	NJ	ZIP	07065-0907
Country	USA	Telephone	(732)594-6734	Fax	(732)594-4720

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name of Sole or First Inventor:	<input type="checkbox"/> A petition has been filed for this unsigned inventor				
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Qingyun	Liu				
Inventor's Signature					
Residence: City	North Wales	State	PA	Country	US
Post Office Address	Merck & Co., Inc., P.O. Box 2000				
City	Rahway	State	NJ	ZIP	07065-0907
<input checked="" type="checkbox"/> Additional inventors are being named on the <u>2</u> supplemental Additional Inventors(s) sheet(s) PTO/SB/02A attached hereto.					



## DECLARATION AND POWER OF ATTORNEY

ADDITIONAL INVENTOR(S)  
Supplemental Sheet

Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor					
Given Name (first and middle [if any])		Family Name or Surname					
Terrence		McDonald					
Inventor's Signature	<i>Terrence McDonald</i>			Date	August 03, 2000		
Residence: City	Langhorne	State	PA PA	Country	US	Citizenship	US
Post Office Address	Merck & Co., Inc., P.O. Box 2000						
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Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor					
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Timothy P.		Bonnert					
Inventor's Signature				Date			
Residence: City	Hartfordshire	State		Country	UK	Citizenship	UK
Post Office Address	Merck & Co., Inc., P.O. Box 2000						
City	Rahway	State	NJ	ZIP	07065-0907		
Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor					
Given Name (first and middle [if any])		Family Name or Surname					
Gordon		Ng					
Inventor's Signature				Date			
Residence: City	Point-Claire	State		Country	CA	Citizenship	CA
Post Office Address	Merck & Co., Inc., P.O. Box 2000						
City	Rahway	State	NJ	ZIP	07065-0907		
Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor					
Given Name (first and middle [if any])		Family Name or Surname					
Lee F.		Kolakowski, Jr.					
Inventor's Signature				Date			
Residence: City	San Antonio	State	TX	Country	Us	Citizenship	US
Post Office Address	Merck & Co., Inc., P.O. Box 2000						
City	Rahway	State	NJ	ZIP	07065-0907		

## DECLARATION AND POWER OF ATTORNEY

ADDITIONAL INVENTOR(S)  
Supplemental Sheet

Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor					
Given Name (first and middle [if any])		Family Name or Surname					
Janet		Clark					
Inventor's Signature					Date		
Residence: City	Bethesda	State	MD	Country	US	Citizenship	US
Post Office Address	Merck & Co., Inc., P.O. Box 2000						
City	Rahway	State	NJ	ZIP	07065-0907		
Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor					
Given Name (first and middle [if any])		Family Name or Surname					
Tom I.		Bonner					
Inventor's Signature					Date		
Residence: City	Bethesda	State	MD	Country	US	Citizenship	US
Post Office Address	Merck & Co., Inc., P.O. Box 2000						
City	Rahway	State	NJ	ZIP	07065-0907		
Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor					
Given Name (first and middle [if any])		Family Name or Surname					
Inventor's Signature					Date		
Residence: City		State		Country		Citizenship	
Post Office Address	Merck & Co., Inc., P.O. Box 2000						
City	Rahway	State	NJ	ZIP	07065-0907		
Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor					
Given Name (first and middle [if any])		Family Name or Surname					
Inventor's Signature					Date		
Residence: City		State		Country		Citizenship	
Post Office Address	Merck & Co., Inc., P.O. Box 2000						
City	Rahway	State	NJ	ZIP	07065-0907		

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<b>First Named Inventor</b>		
Liu, et al.		
<b>COMPLETE IF KNOWN</b>		
Application Number		
09/601,582		
Filing Date		
Group Art Unit		
Examiner Name		

**As a below named inventor, I hereby declare that:**

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

NOVEL GABAB RECEPTOR DNA SEQUENCES

*(Title of the Invention)*

the specification of which

is attached hereto

OR

was filed on (MM/DD/YYYY)  as United States Application Number or PCT International

Application Number  and was amended on (MM/DD/YYYY)  (if applicable).

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Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Attorney Docket Number	Priority Claimed? YES <input checked="" type="checkbox"/> NO <input type="checkbox"/>
PCT/US99/02361	02/03/1999			<input checked="" type="checkbox"/> <input type="checkbox"/>
				<input type="checkbox"/> <input type="checkbox"/>
				<input type="checkbox"/> <input type="checkbox"/>
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Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

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Application Number(s)	Filing Date (MM/DD/YYYY)	Attorney Docket Number
60/073,767	02/05/1998	20052PV

## DECLARATION AND POWER OF ATTORNEY for Utility or Design Patent Application

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Customer Number  →  Place Customer Number  
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 Registered practitioner(s) name/registration number listed below

Name	Registration Number	Name	Registration Number
Joseph A. Coppola	38,413	Jack L. Tribble	32,633

Direct all correspondence to:  Customer Number or Bar Code Label

**000210**

Name	Joseph A. Coppola				
Address	Merck & Co., Inc. - Patent Department				
Address	P.O. Box 2000, RY60-30				
City	Rahway	State	NJ	ZIP	07065-0907
Country	USA	Telephone	(732)594-6734	Fax	(732)594-4720

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Given Name (first and middle [if any])	Family Name or Surname				
Qingyun	Liu				
Inventor's Signature					
Residence: City	North Wales	State	PA	Country	US
Post Office Address	Merck & Co., Inc., P.O. Box 2000				
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ADDITIONAL INVENTOR(S)  
Supplemental Sheet

Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor					
Given Name (first and middle [if any])		Family Name or Surname					
Terrence		McDonald					
Inventor's Signature					Date		
Residence: City	Langhorne	State	PA	Country	US	Citizenship	US
Post Office Address	Merck & Co., Inc., P.O. Box 2000						
City	Rahway	State	NJ	ZIP	07065-0907		
Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor					
Given Name (first and middle [if any])		Family Name or Surname					
Timothy P.		Bonnert					
Inventor's Signature	<i>Timothy P. Bonnert</i>				Date	August 15 2000	
Residence: City	Hartfordshire	State		Country	UK	Citizenship	UK
Post Office Address	Merck & Co., Inc., P.O. Box 2000						
City	Rahway	State	NJ	ZIP	07065-0907		
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Gordon		Ng					
Inventor's Signature					Date		
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Lee F.		Kolakowski, Jr.					
Inventor's Signature					Date		
Residence: City	San Antonio	State	TX	Country	Us	Citizenship	US
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Janet		Clark					
Inventor's Signature					Date		
Residence: City	Bethesda	State	MD	Country	US	Citizenship	US
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Inventor's Signature					Date		
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PATENT APPLICATION  
(37 CFR 1.63)**

Declaration Submitted with Initial Filing

OR

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Attorney Docket Number	20052YP
First Named Inventor	Liu, et al.
<b>COMPLETE IF KNOWN</b>	
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Inventor's Signature	<i>Sarah Ws</i>				Date	<i>August 3, 2000</i>	
Residence: City	Point-Claire	State		Country	CA	Citizenship	CA
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000210

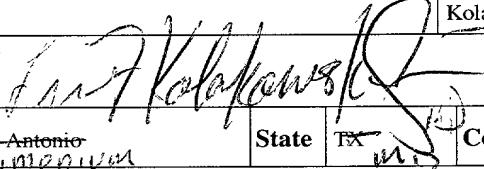
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DEC 04 2000  
SUBSTITUTE for PTO/SB/01 (2-97), DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION  
PATENT & TRADEMARK OFFICE  
REF ID: A147

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OR

was filed on (MM/DD/YYYY)  as United States Application Number or PCT International

Application Number  and was amended on (MM/DD/YYYY)  (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose to the Patent and Trademark Office all information known to me to be material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Attorney Docket Number	Priority Claimed? YES <input checked="" type="checkbox"/> NO <input type="checkbox"/>
PCT/US99/02361	02/03/1999			<input checked="" type="checkbox"/> <input type="checkbox"/>
				<input type="checkbox"/> <input type="checkbox"/>
				<input type="checkbox"/> <input type="checkbox"/>
				<input type="checkbox"/> <input type="checkbox"/>

Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)	Attorney Docket Number
60/073,767	02/05/1998	20052PV

## DECLARATION AND POWER OF ATTORNEY for Utility or Design Patent Application

I hereby claim the benefit under 35 U.S.C 120 of any United States application(s), or 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose information known to me to be material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application or PCT Parent Application Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number (if applicable)
PCT/US99/02361	02/03/1999	
60/073,767	02/05/2098	

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As a named inventor, I hereby appoint, respectively and individually, as my attorneys or agents with full power of substitution and revocation, the following registered practitioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Customer Number   → Place Customer Number Bar Code Label here  
 OR  
 Registered practitioner(s) name/registration number listed below

Name	Registration Number	Name	Registration Number
Joseph A. Coppola	38,413	Jack L. Tribble	32,633

Direct all correspondence to:  Customer Number or Bar Code Label

000210

Name	Joseph A. Coppola				
Address	Merck & Co., Inc. - Patent Department				
Address	P.O. Box 2000, RY60-30				
City	Rahway	State	NJ	ZIP	07065-0907
Country	USA	Telephone	(732)594-6734	Fax	(732)594-4720

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name of Sole or First Inventor:	<input type="checkbox"/> A petition has been filed for this unsigned inventor				
Given Name (first and middle [if any])	Family Name or Surname				
Qingyun	Liu				
Inventor's Signature					Date
Residence: City	North Wales	State	PA	Country	US
Post Office Address	Merck & Co., Inc., P.O. Box 2000				
City	Rahway	State	NJ	ZIP	07065-0907
<input checked="" type="checkbox"/> Additional inventors are being named on the <u>2</u> supplemental Additional Inventors(s) sheet(s) PTO/SB/02A attached hereto.					

## DECLARATION AND POWER OF ATTORNEY

ADDITIONAL INVENTOR(S)  
Supplemental Sheet

Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor					
Given Name (first and middle [if any])		Family Name or Surname					
Terrence		McDonald					
Inventor's Signature					Date		
Residence: City	Langhorne	State	PA	Country	US	Citizenship	US
Post Office Address	Merck & Co., Inc., P.O. Box 2000						
City	Rahway	State	NJ	ZIP	07065-0907		
Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor					
Given Name (first and middle [if any])		Family Name or Surname					
Timothy P.		Bonnert					
Inventor's Signature					Date		
Residence: City	Hartfordshire	State		Country	UK	Citizenship	UK
Post Office Address	Merck & Co., Inc., P.O. Box 2000						
City	Rahway	State	NJ	ZIP	07065-0907		
Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor					
Given Name (first and middle [if any])		Family Name or Surname					
Gordon		Ng					
Inventor's Signature					Date		
Residence: City	Point-Claire	State		Country	CA	Citizenship	CA
Post Office Address	Merck & Co., Inc., P.O. Box 2000						
City	Rahway	State	NJ	ZIP	07065-0907		
Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor					
Given Name (first and middle [if any])		Family Name or Surname					
Lee F.		Kolakowski, Jr.					
Inventor's Signature					Date		
Residence: City	San Antonio	State	TX	Country	Us	Citizenship	US
Post Office Address	Merck & Co., Inc., P.O. Box 2000						
City	Rahway	State	NJ	ZIP	07065-0907		

## DECLARATION AND POWER OF ATTORNEY

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Supplemental Sheet

Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor					
Given Name (first and middle [if any])		Family Name or Surname					
Janet		Clark					
Inventor's Signature	<i>Janet Clark</i>			Date	21 - Aug - 2000		
Residence: City	Bethesda	State	MD	Country	US	Citizenship	US
Post Office Address	Merck & Co., Inc., P.O. Box 2000						
City	Rahway	State	NJ	ZIP	07065-0907		
Name of Additional Joint Inventor, if any:		<input type="checkbox"/> A petition has been filed for this unsigned inventor					
Given Name (first and middle [if any])		Family Name or Surname					
Tom I.		Bonner					
Inventor's Signature				Date			
Residence: City	Bethesda	State	MD	Country	US	Citizenship	US
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**DECLARATION AND  
POWER OF ATTORNEY  
FOR UTILITY OR DESIGN  
PATENT APPLICATION  
(37 CFR 1.63)**

Declaration Submitted with Initial Filing

OR

Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	20052YP
First Named Inventor	Liu, et al.
<b>COMPLETE IF KNOWN</b>	
Application Number	09/601,582
Filing Date	
Group Art Unit	
Examiner Name	

**As a below named inventor, I hereby declare that:**

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

NOVEL GABAB RECEPTOR DNA SEQUENCES

*(Title of the Invention)*

the specification of which

is attached hereto

OR

was filed on (MM/DD/YYYY)  as United States Application Number or PCT International

Application Number  and was amended on (MM/DD/YYYY)  (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

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PCT/US99/02361	02/03/1999	
60/073,767	02/05/2098	

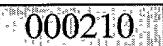
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Customer Number   →    Place Customer Number  
OR    Registered practitioner(s) name/registration number listed below  

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Given Name (first and middle [if any])			Family Name or Surname				
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Given Name (first and middle [if any])		Family Name or Surname					
Tom I.		Bonner					
Inventor's Signature	<i>Tom I. Bonner</i>				Date	8/28/00	
Residence: City	Bethesda	State	MD	Country	US	Citizenship	US
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